FLOOD VULNERABILITY ASSESSMENT WITHIN BENIN METROPOLIS, USING REMOTE SENSING AND GIS TECHNOLOGY

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SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A BACHELOR OF SCIENCES {BSCGEM - B.SC. GEOMATICS} DEGREE, IN THE FACULTY OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA.

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FLOOD VULNERABILITY ASSESSMENT WITHIN BENIN METROPOLIS, USING REMOTE SENSING AND GIS TECHNOLOGY (ANALYTICAL HIERARCHY PROCESS)

A PROJECT SUBMITTED

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Certification

This is to certify that this project was carried out by OVIAWE ODUAGBON CAESAR with Matriculation Number: ENV1604564 of the Department of Geomatics, Faculty of Environmental Sciences, University of Benin, Edo State, Nigeria.

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EXTERNAL EXAMINER Date

Dedication

I humbly dedicate this project to God almighty for his grace upon my life and to my parents (Mr Samuel Oviawe and Mrs Susan Oviawe), and my beloved brothers and sister for their support in all ramifications. May God continue to bless you all, Amen.

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I say God bless you all, Amen.

ABSTRACT

Flooding brought on by excessive rainfall is one of the frequently occurring and widely reported disasters affecting human existence. The purpose of this study is to create flood risk maps of Ikpoba Okha which can be used for predicting the level of vulnerability due to rapid urban development taking place in recent times. The procedure to achieve this involved using the method of Analytical Hierarchy Process (AHP) in a Geographic Information System (GIS) environment. Among the fundamental datasets requirements for the project were: cloud-free high-resolution satellite images, SRTM DEM data, FAO soil data, rainfall data, etc. Maps of flood-enhancing elements, such as flood risk vulnerability mapping, were created in Geographic Information Systems using the same scale of 1: 200,000 and geographic coordinate system (WGS 1984 UTM zone 31N). This multi-parametric technique includes rainfall distribution, elevation and slope, drainage network and density, land use/land cover, and soil type, among other flood determinants. All the output raster maps were first ranked using the "Weighted Linear Combination" method with a grid cell size of 0.0028 mm before being sent for Multi-Criteria Analysis (MCA). The computation of the consistency ratio at an acceptable level of 0.055 further confirmed the model's validity. Additionally, the research found topography and rainfall as the most significant factors contributing to floods in Benin City.

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CHAPTER ONE

1.0 Introduction

1.1 Background

This study is concerned with using remote sensing methodology to assess flood vulnerability in a flood-prone area. A flood can be defined as the temporary overflow of water onto land that is normally dry. A flood can also be defined as a large volume of water that 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). Floods are anticipated to happen due to rapid urban development, declined groundwater recharge by extension of impermeable surfaces in urban areas, changes in land-use patterns, and climatic changes (Balaban 2009).

Over the years, flood has been one of the most frequent types of natural disasters it occurs in the world, therefore, the desire to mitigate the flood problem cannot be overemphasized. Flooding hinders economic growth and development because of the high cost of relief and recovery associated with the flood. Infrequently 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, spreading over to land next to it. Flooding has been caused majorly by heavy rainfall/downpour, especially by areas experiencing regular rainfall, in other cases also include overflowing rivers, broken, dams, etc.

Flood disaster in Nigeria has done great harm to the victims and affected area, it is the most common environmental hazard in Nigeria (Samson, 2015). Flood occurs in Nigeria in three forms: Urban Flooding, Coastal Flooding, and River Flooding (Folorunsho, 2001). Urban floods occur in towns with low or flat terrain, especially where no provision has been made for surface drainage, or where the existing drainage has been blocked with municipal waste, eroded soil sediments and refuses (Folorunsho, 2001) Coastal flood is a result of a combination of sea tidal surges, barometric pressure and high winds (Anon, 2021) River flood occurs in the flood plains of larger rivers.

Managing floods to safeguard the people and the environment is the main responsibility of city authorities in flood-prone areas. In other to achieve this goal, vulnerability reduction and increasing resilience are significant approaches. One of the main steps in this process is measuring vulnerability to identify the vulnerable areas (Takemoto, 2011) and adopting effective measures. Indeed, urban flood vulnerability varies from time to time and in diverse places because of environmental conditions, the culture of society, and human activities in face of threats (Ahmad and Simonovic 2013). Increasing assessment methods and improving understanding of flood risk vulnerability can support decision-makers in decreasing damage and mortalities. Different assessment methods of flood vulnerability have been developed over the years. Flooding is one of the major environmental crises ravaging the universe (United Nations Environmental Programme UNEP, 2010). A flood is a body of water that rises over land which not normally submerged (Nigeria Environmental Study and Action Team, 1991).

Remote sensing is a technique to observe the earth's surface or the atmosphere from out of space using satellites or from the air using aircraft that are airborne (Aggarwal, 2019). 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/terrain (radiance) is influenced by both the properties of the object/terrain.

Remote sensing technologies are powerful and excellent tools for mapping the spatial distribution of disaster-related data within a short period. Remote sensing systems on satellites and aircraft can provide much of the required information for delineating flood-affected areas, enabling monitoring, assessing the damage, and feeding models that can predict the vulnerability to flooding of inland and coastal areas (Klimas, 2015).

1.2 Statement of the problem

Vulnerability in flood studies is considered as the extent of harm that is expected under certain conditions of exposure, susceptibility, and resilience. In the Ikpoba-Okha Local Government Area of Edo State, persistent flooding has resulted in building destruction, property loss, and fatalities.

Flooding has caused and initiated well-known gullies like Queen Ede, Ogbesan, and others, which has added to environmental degradation and raised serious concerns for those who live nearby. Traffic snarls, vehicles being submerged, and drivers and pedestrians misjudging the width of the road are just a few of the immediate effects of flooding. To properly advise relevant authorities and decision-makers, it is crucial at this point to use the data at hand to assess the vulnerability risk.

1.3 Aim and Objectives

This project aimed at assessing areas vulnerable to flood within the Benin metropolis, using remote sensing data and GIS-based techniques to delineate the area that is vulnerable to flood risk within the study area.

The following are the objectives of the project

i. To acquire relevant remote sensing data for analysis.

ii. To delineate the extent of the study area using the existing topography map.

iii. To determine the contribution of various factors controlling flood hazards in the study area.

iv. To implement a GIS-based analytic hierarchy process for the creation of flood vulnerability maps.

1.4 Scope of Study

For this study, A Raster and Vector Model will be used, Raster Model will be used to obtain important details during the cause of this project. QGIS and ArcGIS software will be used for analysis. DEM data and rainfall data will be downloaded from the United State Geological Survey USGS geo-portal (Earth explorer).

The vector data model, point, lines, and polygon form the basic units of terrain features; River is represented as a line feature and the road as a line feature. For this research, the following analysis meant for any GIS application was carried out in the conceptual data modelling.

i. Identification of basic geometric and thematic features,

ii. Identification of the relationship among the basic entities,

iii. Identification of related datasets.

The logical design is the representation of the conceptual design into data structure using Hierarchical, Network, and Relational data models in a computer system.

Using remote sensing satellite technology to show the area affected by flood in the study area and also use remote sensing technology to acquire data for the analysis, to create a topography map, soil map, drainage map, slope map, and rainfall map of the study area, and also using Analytic Hierarchy Process and GIS software to create a Flood Vulnerability Map.

1.5 Justification

Flooding has been a serious environmental threat and the AHP-GIS-based approach to flood risk assessment used in this project is considered to be reasonably inexpensive, simple to use, and, most significantly, allows flood managers to interact with the data for continuous improvement. This is because flood managers can utilize the AHP rating indices and numerical findings as a reference for flood management planning and flood defence.

1.6 Limitation

The limitation observed in this work includes: the accuracy of the final results hinged on the spatial resolution of the imageries, the soil map used is of low classification and may affect some areas being generalized, and climate change may introduce a certain number of errors. The outcome is limited to the study area

CHAPTER TWO

2.0 Literature Review

2.1 Flooding vulnerability assessment

A flood is the overflowing or eruption of a great body of water over land not usually submerged (Giuseppe et al., 2019). Flood Vulnerability assessment, assess vulnerability to inform decision-makers or specific stakeholders about options for adapting to the impact of flooding hazards (Double, 2006).

Over the years, flood cases have been reported in Nigeria and are linked with heavy rainfall, illegal construction of buildings across the drainage, inadequate drainage, climate change, blockage of drainage, and population expansion, especially in urban areas (Adeoye *et al*., 2009). Furthermore, it has been reported that population growth, reclassification of habitats, land-use change, migration, and change in settlement patterns have triggered a series of floods, especially in areas located close to rivers or streams (Isma'il and Saanyol, 2013). This is because the change in land use pattern has a direct relationship with hydrological characteristics such as a reduction in the level of infiltration, and an increase in n-off in frequency and flood height (Alaghmand *et al*., 2010). However, the origin of inundations may be the breaching or overtopping of coast or drainage defences by the flowing water or discharges by drainage beyond their bank's full capacity.

Flood risk is a function or a product of hazard and vulnerability (Ologunorisa, 2005). That is (Risk = Hazard x Vulnerability). A real flood risk level requires a certain level of hazard and a certain level of vulnerability for the same location. A situation of risk is due to the incompatibility between hazard and vulnerability levels on the same land plot.

Flood hazard mapping and flood inundation modelling are vital components in flood mitigation measures and land use planning (Izinyon, 2011). Advances in geospatial technologies (Geographic Position System, Remote sensing, and Geographic Information System) have enabled the acquisition of data and analysis of the river basin for flood mitigation projects (either structural or non-structural) in a faster and more accurate manner (Ishaya *et al*., 2009). GIS facilitates include integration of spatial and non-spatial geographical data such as rainfall and streamflow analysis (Jayasselan, 2006). Flood maps prepared using satellite imageries of real flood events and information from the ground are useful for flood damage assessment and future flood mitigation planning.

Flood disasters such as structural and erosion damage, contamination of food and water, the spread of diseases, disruption of socio-economic activities as well as loss of life and biomass have led to several environmental havoc (Isma'il and Saanyol, 2013).

Environmental interaction is linked to land-use changes that affect physical and biochemical processes because people and nature are linked in complex ways in a system that is constantly changing (Botkin and Keller, 2010). Although, some changes occur naturally many are directly or indirectly attributed to human-induced activities.

According to (Hajar et al., 2016). One of the aims of flood vulnerability assessment is to make a clear association between the theoretical conceptions of flood vulnerability and the daily administrative process. There have been so many approaches to flood assessment, few methods are categorized into four groups: curve method, disaster loss data method indicator-based method, and computer modelling method. The various methods below would be reviewed and compared with their benefits and drawbacks.

According to Dapeng, (2012), vulnerability assessment methods are categorized into four distinct groups as discussed further:

i. Vulnerability curve method

Flood risk and elements can be studied by empirical damage or fragility curves which show the relation between them. Data for this approach are found in well-documented case studies which are typically restricted to a specific area. The data are picked from each sample group. The data for all samples of each component class is averaged and step-damage curves are created. The stage-damage curves are for potential damage, although similar methods can be used to measure the damage that happens immediately after a flood (real damage analyses). This method is based on an actual damage survey, it takes a lot of time and resources and this method is not always reliable because it does not apply to other regions.

ii. Disaster loss data method

This method is based on the collection of data from real flood hazard and their usage, such as director to upcoming events. This method is a simple approach but it's a little inaccurate because of unevenly recorded data, results from this method are handled with caution.

iii. The vulnerability indicators method

This method adapts the use of available data for providing a logical image of the vulnerable place. This method is widely used in flood vulnerability studies and policymakers prefer it because it clarifies vulnerability image over space, it priories measures and plans for the risk response in a specific region. This group of methods depends on complicated indices with and without weighting, however, this method is faced with considerable complexities related to standardization, weighting, and aggregation methods. Uncertainty is one of the major struggles with this method. Since each additive layer includes a diverse variable, the struggle about variable interdependences must be fixed. The best solution is to weight variables to reduce their impact in forming a final expression (Lein, 2010). The quantification of several social indicators is one of the weaknesses as it is difficult to calculate (Khan, 2012). There are two theoretical approaches for indicator selection in this method, the theory-based (deductive) and the data-based (inductive) approach. These attitudes are different in methodology, but together they make a better perception of local vulnerability. The deductive approach is built on a theoretical framework for selecting appropriate indicators while the inductive approach selects indicators to regard statistical links with observed vulnerability consequences (e.g., deaths from floods). Because there is no clear definition of vulnerability consequences for the development of aggregated indices, the data-based approach is only useful for specific flood exposure systems. Development and testing of an index in circumstances where dealing with short-term instability is the significant limitation of all data-based indexes (Füssel, 2009).

iv. Modelling methods

Computer models can evaluate the elevation, depth, and velocity of a flood using the frequency, magnitude, and shape of the hydrography. To compute flood inundation, one (1D) or two-dimensional (2D) models which are based on solutions of full or approximate forms of the surface water equations are prevalent. This method depends on detailed data about topographic, hydro-graphic, and economic information in the study region for its accuracy. Nevertheless, with the lack of sufficient data, models have suffered significant irregularities which have led to the questioning of validity and mixed up the decision for decision-makers (Balica, 2013). In Geographic Information, system-based vulnerability modelling (GIS) variables used as input data though should be geo-referenced and converted to raster format for a tangible analysis. The modelling method can assess vulnerability on a local scale, more sensitive than other ones because it considers local factors, however, cannot describe the clear link between the predicted map and the level of real flood damage (Lein, 2010). Improving vulnerability assessment measurement is necessary. An environment in which man lives to provide the basic sustenance needed for existence. A sustainable environment supports the lives of plants, animals, and microorganisms (Allaby, 2002).

According to (Joy, 2005), Landsat ETM+ and ERS synthetic aperture radar (SAR) imageries are used to classify non-flooded areas and flood depth within flooded zones, and to delineate human settlements at the village level. The high spatial resolution of satellite imageries enables us to obtain detailed classification results that are suitable for formulating planning measures on a small scale. An added advantage is that the high-resolution hydrologic information can be conveniently integrated with demographic data collected from smaller administrative units. This would greatly enhance the capability of the spatial database to estimate the vulnerability of individual settlements to an extreme flood event. Data sources are satellite images, Semi-automatic digital image processing techniques and manual digitization was employed to extract the relevant information from remotely sensed data. Then the incorporation of demographic parameters with the information extracted from satellite imageries to identify effectively the settlements that are highly vulnerable to flood hazards.

According to (Hery et al., 2017). The data used in the research was divided into two types based on data sources, which are primary data and secondary data. Primary data are data obtained from field observation, including observation of all districts in the Study Area and their documentation, while secondary data is obtained from satellite image data and related institutions. The methodology adopted by the study is given in Figure 3.2.

After carrying out the project, they analyzed the map of each factor to get the final results. They noticed that the main causes of Sidoarjo flooding are rainfall, drainage density, topography, and land cover. Floods can be divided into 2 (two) kinds of events i.e floods that occur in areas that are usually not flooded and flood events that occur due to floodwaters from the river because the flood discharge is greater than capacity (Kodoatie, 2002). A flood event itself is not a problem if it does not interfere with human activities in conducting activities in flood areas. It is necessary to regulate the flood plains, to reduce the loss due to flooding. So in other words flood events will not be a problem or not natural disaster (natural hazard) when the flood is not disturbing or harmful to humans. The list of necessary data along with their source.

Nwabueze, (2014), carried out research to address a flood problem in Agenebode using remote sensing and GIS, to create a flood hazard map of the area to assign remedial activities in case of future occurrence. Spatial data for the project was satellite imagery and a Digital map of the study area. All geospatial data for this project were imported into the GIS environment, after which georeferencing was done using the four coordinates points obtained from the net of four known points, using the Universal Transverse Mercator System (UTM), the georeferenced satellite image was then converted from raster to vector in the GIS environment through digitization techniques. The attribute data which was the previous flood height measured 40 - 45m and the distance of the last flood from the bank of the river measured 2km, were used to create the buffer of the study area. The buffer was then used to calculate the number of people affected by the flood using 60 - 65m as the safe elevation, and it was found that 4,012 people will be safe from the flood.

According to (Konwea, 2012), described the flood that occurred in the year 2012 as the worst flood Nigeria has seen in at least half a century when the Lagos dam upstream of River Benue in the Republic of Cameroon resulted in serious floods in the states of Adamawa, Taraba, Benue, Nassarawa, Plateau, Kogi, and Edo. These states are located downstream of River Benue in Nigeria. The flood led to the deaths of hundreds of Nigerians, displaced over a million people, and destruction of hundreds of thousands of hectares of farmland. Huge swathes of the country have been affected, particularly in central and south-eastern regions, with houses, bridges and roads devastated. Oredo, Egor, and Ikpoba-Okha Local Government Council is not an exception and indeed this study area has a series of flooding that have affected inhabitants and disrupted socio-economic activities.

2.2 Flood Characteristics

i. Flood frequency: Flood frequency is the concept of the probable frequency of occurrence of a given flood (Duncan, 2005). Flood frequency information is commonly applied /used in controlling land use and settlement in flood-prone areas. Flood frequency estimates are particularly important in densely populated urban areas.

ii. Flood Duration: The duration of a flood event means how often the flooding occurs in a given period (M&E Studies, 2019). This parameter is very important as it helps in determining and ascertaining the extent of flood impact, particularly on individual and affected communities (Bariweni, 2012)

iii. Flood Intensity: The intensity of a flood is the damage caused by it. It can be characterized by the depth of inundation, the volume of inundation, the velocity of flow, and the rate of rising of water. (The more depth of water, the more will be its volume, velocity, and its damaging capacity). A high rate of rising water also means less preparation time for people in the area (M&E Studies, 2019).

2.3 Types of Floods

Floods can happen anywhere, at any time, and are one of the most common weather hazards on the planet. Floods can happen in a matter of seconds. Flood effects can be localized, affecting a single neighbourhood or community, or they can be widespread, affecting entire river basins and multiple areas (NOAA, 2013). Flooding is divided into several categories.

According to the New Delhi Municipal Corporation (2012), floods are classified as follows

Based on the duration and location of the flood:

(i) Slow-Onset Flooding (ii) Rapid-Onset Flooding (iii) Flash Flooding

Based on the duration of the flood.

(i) Coastal Flooding (ii) Arroyo's Flooding (iii) River Flooding (iv) Urban Flooding (based on the location of the flood).

Flood types can be classified or named in a variety of ways. For example, Bariweni et al. (2012) classified floods as follows:

a. Tidal flooding: a combination of low-pressure weather systems and peak high tides that can overtop or breach both sea and river defences. Storms with strong winds produce large, powerful waves, and low-pressure fronts cause sea levels to rise above normal. High tide levels vary with the lunar and solar cycles, and when these variations are combined with other tidal variations, exceptionally high tides result. The onset of these floods from the sea and tidal rivers is frequently abrupt, and the extreme forces that drive them pose a serious threat to human life. This type of flood can often be predicted with reasonable accuracy, because of the predictability of the tide and the trackability of low-pressure systems, this type of flooding occurs. Where drainage is available, the duration of this type of flooding is also limited by the tide cycle (Dance and Hynes, 1980). This type of flood is now classified as a coastal flood because of its location, and it can be slow-onset, rapid-onset, or even flash depending on its duration.

b. Fluvial flooding: Flooding occurs in river floodplains when the capacity of watercourses is exceeded due to rainfall or snow and ice melts in catchment areas upstream. Watercourse and flood channel blockages could result in rising water levels. Increased water levels may then overtop river defences, or large objects of debris carried at high water speeds may breach them. In some catchments with steadily rising water levels, the onset of this type of flood can be quite slow. This flood type is a river in nature, but depending on the speed of the water or the nature of the land, it may be flash or slow-onset.

c. Flash flooding: Flash flooding is a type of flooding that occurs in steep catchments and is much more severe. River flooding, particularly in well-known floodplains, can usually be predicted with reasonable accuracy. Flash floods caused by sudden downpours, on the other hand, continue to test the detection and forecasting systems' capabilities. Water that is deeper than 250 mm can carry debris and be very cold, especially in urban areas. Even at low speeds, this can be extremely dangerous to those who are caught in it.

d. Groundwater flooding: As groundwater levels rise, low-lying areas adjacent to aquifers may flood. This type of flooding is frequently seasonal and thus can be accurately forecasted; however, it is often slow, to begin with.

e. Pluvial flooding: Surface water flooding is caused by rainwater runoff from low-absorbent urban and rural land. Increased development intensity in urban areas has resulted in more land with non-permeable surfaces, a problem exacerbated by overburdened and out-of-date drainage infrastructure. These conditions, when combined with heavy rain, can result in localized flooding. This type of flooding frequently occurs outside of recognized floodplains, and it is difficult to predict because it is caused by very localized weather conditions. Its onset can also be quite rapid, and the flooding can be quite severe.

f. Sewer flooding: Sewer flooding occurs when the capacity of combined storm and foul sewers is exceeded due to large amounts of surface water run-off in a short period. Drainage blockages can occur as a result of poor cleaning and maintenance, resulting in local flooding. This type of flooding is difficult to predict, has serious sanitary implications for those affected, and can happen very quickly.

g. Man-made infrastructure flooding: Canals, reservoirs, and other man-made structures can fail, resulting in flooding in downstream areas. Industrial activities, water mains, and pumping stations can all fail, resulting in flooding, though this is rare.

2.4 Causes of Flooding in Nigeria

The occurrence of prolonged heavy rain and its recurrence in the southern part of Nigeria within a few months of the dry season are reported in newspapers and magazines, as well as television stations, the occurrence of flood disasters (Dow and Dowing, 2006; Kesh and Simon, 2005).

Floods are caused by a variety of factors including heavy rainfall, highly accelerated snowmelt, severe winds over water, unusually high tide, tsunamis, or the failure of dams, levees, retention ponds, or other similar structures. Increased rainfall can exacerbate flooding. a large amount of impervious surface or other natural phenomena wildfires, which reduce the supply of water, are examples of hazards. vegetation capable of absorbing rain (Welch et al., 1977).

Flooding can be caused by convective precipitation (intense thunderstorms) or the sudden release of water from an upstream impoundment created behind a dam (landslide) (Thompson, 1964). Floods are also caused by a combination of storm-force winds and sea tidal surges. A storm surge, whether from a tropical or extratropical cyclone, is included in this category (Rosenberg and Snor, 1975). Floods can occur as a result of severe sea storms or other hazards, such as a tsunami or hurricanes (Powell, 2009). Floods can also be brought on by a major and unexpected event, such as a dam failure, or by another hazard (e.g., an earthquake or volcanic eruption). Workmen's damage to tunnels or pipes in cities can also result in accidental floods (Esu, 1999). Bariweni and his colleagues (Bariweni et al) (2012).

Other causes of floods are as follows: when rainfall is relatively light, severe winds, such as those experienced during hurricanes, can flood the shorelines of lakes and bays. Extremely high tides, such as spring tides, can flood coastal areas, especially when combined with high winds and storm surges. Tsunamis are large, high-amplitude waves that are typically caused by undersea earthquakes, volcanic eruptions, or massive explosions, and result in seawater flooding buildings near the sea and even beyond. Climate Change is also an attribute that causes flooding, according to Bariweni, et al. (2012), because when the climate warms, it causes the following:

a. Severe rains

b. The relative sea level around most shorelines continues to rise.

c. Extreme Sea level rises will become more common. As a result, climate change is likely to increase the risk of flooding significantly and gradually over time. Low-lying coastal areas, which are not currently prone to fluvial or tidal flooding, will be particularly at risk as sea levels rise, as will areas that are not currently prone to fluvial or tidal flooding, as more intense rainfall leads to a significantly higher risk of flooding from surface runoff and an overwhelmed drainage system. However, according to Etuonovbe (2011), flooding in Nigeria could be caused by natural or human causes, and she divided the causes into the following categories:

Natural occurrences

a. Flooding b. Ocean storms and tidal waves, usually occur along the coast.

c. A scarcity of lakes

d. Silting Causes attributed to humans

Another human-caused flooding in Nigeria could be caused by one of the following: a. burst water main pipes b. dam failures

e. Trespassing on water storm drains is an example of this (a key cause in Southern Nigeria)

f. Unplanned urbanization (a major contributor to urban flooding in many cities).

g. Inadequate Sewerage Management

h. Ignoring hydrological system data warnings (a major cause of 2012 flooding in Nigeria)

i. There are no flood-control measures in place (especially by the government).

2.5 Effects of Flooding

Aside from property damage, flooding has two other significant consequences.

1. Water Damage: Property damage is the most common consequence of flooding. Basements and crawl spaces are frequently the first places to be flooded during flooding. Floods, on the other hand, can cause damage to any part of your home. Flooding can also result in sewage backups, depending on the circumstances. A sewer backup also puts your family and pets in danger.

2. Death: Flooding, while unpleasant, has the potential to kill people. As a result, during severe storms, you should avoid sleeping below ground. Also, if a flood warning is issued, make sure you stay awake. Even if it appears to be safe, you should never walk or drive through a flood. If you're driving during a flood, pull over to the side of the road and wait for the storm to pass.
3. Soil Erosion: Soil erosion is one of the environmental effects of flooding. Floods will carry away loose dirt because they saturate the soil. This is especially dangerous if the soil around your foundation is washed away. Not only could this result in flooding, but it could also cause your home to shift or become unstable. A flood can even result in a sinkhole and mudslide in some cases. Plates 2.1, 2.2, and 2.3 show a scenario of flooded pavement in the study area.

Plate 2.1: showing flood incident in the study area.

Plate 2.2: showing flood incident in the study area.

Plate 2.3: showing flood incident in the study area.

2.6 Remote Sensing

Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites. (NOAA,2021). In contrast to in-situ or on-site observation, remote sensing is the acquisition of information about an object or phenomenon without making physical contact with it. The term is used to describe the process of gathering information about the Earth and other planets (Schowengerdt, 2007). Remote sensing is used in a variety of fields, including geography, land surveying, and most Earth science disciplines (for example, hydrology, ecology, meteorology, oceanography, glaciology, and geology), as well as military, intelligence, commercial, economic, planning, and humanitarian applications (Schott, 2007).

The term "remote sensing" now refers to the detection and classification of objects on Earth using satellite or aircraft-based sensor technologies. Based on propagated signals, it includes the surface, atmosphere, and oceans (e.g., electromagnetic radiation) (Guo et al., 2013). It can be divided into "active" remote sensing (when a signal is emitted by a satellite or aircraft to the object and its reflection is detected by the sensor) and "passive" remote sensing (when a signal is emitted by a satellite or aircraft to the object and its reflection is detected by the sensor) (Liu, 2009).

2.7 Applications of Remote sensing

Aerial traffic control, early warning, and certain large-scale meteorological data are just a few of the applications of remote sensing. Local law enforcement agencies use Doppler radar to monitor speed limits and for enhanced meteorological data such as wind speed and direction within weather systems, as well as precipitation location and intensity. Plasmas in the ionosphere are another type of active collection. To create precise digital elevation models of large-scale terrain, interferometric synthetic aperture radar is used (See RADARSAT, TerraSAR-X, Magellan).

Satellite altimeters, such as laser and radar altimeters, have provided a wealth of information. The map features the seafloor to a resolution of a mile or so by measuring the bulges of water caused by gravity. The altimeters measure wind speeds and directions as well as surface ocean currents and directions by measuring the height and wavelength of ocean waves.

Tides are measured using ultrasonic (acoustic) and radar tide gauges.

The most common instruments in use are radiometers and photometers, which collect reflected and emitted radiation over a wide frequency range. Visible and infrared sensors are the most common, followed by microwave, gamma-ray, and ultraviolet sensors. They can also be used to detect the emission spectra of various chemicals, providing information on atmospheric chemical concentrations. At night, radiometers are used because artificial light emissions are a key indicator of human activity. Remote sensing of population, GDP, and infrastructure damage from war or disasters are some of the applications (Levin et.al., 2020).

Volcanic eruptions can be monitored using radiometers and radar onboard satellites *(*Corradino et.al., 2019)

Imagery and terrain analysts in trafficability and highway departments have frequently used stereographic pairs of aerial photographs to create topographic maps for potential routes, as well as modelling terrestrial habitat features. (Mills; et al., 1997). (Twiss; et al., 2001). (Stewart; et al., 2014).

Since the 1970s, simultaneous multi-spectral platforms such as Landsat have been in use. These thematic mappers are typically found on Earth observation satellites, such as the Landsat program or the IKONOS satellite, and take images in multiple wavelengths of electromagnetic radiation (multi-spectral). Thematic modelling maps of land cover and land use can be used to prospect for minerals, detect or monitor land use, detect invasive vegetation, and deforestation, and examine the health of indigenous plants and crops (satellite crop monitoring), as well as entire farming regions or forests. Janet Franklin and Ruth DeFries are two well-known scientists who use remote sensing for this purpose. Regulatory agencies such as KYDOW use Landsat images to determine water quality.

With imaging narrow spectral bands over a continuous spectral range, hyperspectral imaging produces an image in which each pixel has full spectral information. Mineralogy, biology, defence, and environmental measurements are just a few of the applications for hyperspectral imagers.

In the fight against desertification, remote sensing enables researchers to track and monitor risk areas over time, identify desertification factors, assist decision-makers in defining relevant environmental management measures, and assess their effects (Begni et al., 2021).

2.7.1 Remote Sensing in Flood Monitoring

Floods can be mapped and monitored using data collected by aircraft and satellites, as well as data collected from ground-based platforms. There are numerous sensors and data processing techniques available to gather information about floods. Flood-recording instruments can work in the visible, thermal, and microwave ranges of the electromagnetic spectrum. Active radar is invaluable for monitoring floods due to the limitations posed by adverse weather conditions during flood events; however, if a visible image of flooding can be obtained, retrieving useful information from this is often more straightforward (Guy,2015). Apart from providing direct information about flooding, remote sensing data can also be used to supplement the amount and type of information available for effective flood management by integrating it with flood models (via model calibration or validation, and data assimilation techniques) or providing floodplain topography data. Since the late 1990s, there have been notable studies on integrating remotely sensed data with flood modelling, and there is now a consensus among space agencies to improve the support that satellite missions can provide. This trend has sparked more research in the field, and significant progress has been made in recent years in advancing our understanding of how remote sensing can aid flood monitoring and management. Contributed articles cover a wide range of topics from local to global scale applications (e.g., disaster management and societal impact, flood forecasting, rainfall-runoff modelling DEM processing, water quality, and wetlands). For example, (Schroeder et al, 2015) used satellite microwave data to create a global, multi-year fractional surface water index. (Revilla-Romero et al, 2015) demonstrate the use of a similar index to supplement global flood forecasting, and (Revilla-Romero et al, 2015) demonstrate the potential of combining multi-annual satellite flood maps and modelling to improve flood hazard mapping capabilities (Giustarini et al, 2015) At a more regional to local scale, imagery can be used to detect localized flooding (Malinowski, et al, 2015), assist rapid response (Chung, et al, 2015), infer flood damages (Kwak, et al, 2015), and even map temporal change (Byun, Y., et al, 2015). (Yuan, T et al, 2015), flood regimes and inundation dynamics (Martinis, et al.,2015) (Hu, et al., 2015). Some of the papers in this Special Issue also show that combining satellite flood maps with digital elevation models (DEMs) and distributed process models can yield significant benefits. When zonal flood data is combined with topography, it can reveal complexities in water surface dynamics (Wu, et al., 2015), (Zhang, P. et al., 2015), and local flow connectivity (Poppengra, et al., 2015) that are difficult to detect with flood imagery or maps alone. As shown by (Pinel et al, 2015) in the Amazon Basin and (Jung and Jasinski, 2015) in the Atchafalaya Basin, combining satellite data with models can lead to significant improvements in the latter, particularly for large-scale flood hydrology and hydrodynamics. As demonstrated by (Reager et al, 2015) for a land surface model and GRACE terrestrial water storage, and (Massari et al, 2015) for satellite soil moisture and a rainfall-runoff model, data assimilation of remotely sensed data can be used to help improve simulations from various types of models. With the proliferation of free Earth Observation data now and in the future, there is a clear need to not only understand the limitations and errors of the data and methods, (Ticehurst et al, 2015) and (Devlin et al, 2015) have done for flood mapping and river plume monitoring but also to develop more sophisticated data processing algorithms (e.g., Feng, et al., 2015) and robust frameworks for handling the many heterogeneous databases (Chen, et al., 2015)

2.8 Flood Vulnerability Mapping with Spatial Data and Multi-Criteria Evaluation

Flooding risk is made up of two components: hazard and vulnerability. Threatening events, or the likelihood of a potentially damaging phenomenon occurring within a given period and area, are examples of hazards. The extent of damage caused by a hazardous event is determined by the elements at risk. The population, buildings and civil engineering structures, economic activities, public services, and infrastructure are all at risk (Barroca, B. et al, 2006). Vulnerability, on the other hand, is the most important aspect of risk because it determines whether or not a hazard poses a risk that could lead to a disaster. If the threat of flooding materializes, i.e., when floodwaters physically encroach on a populated area or infrastructure, the degree of harm and damage is determined by the vulnerability of people and infrastructure. The dense concentration of potentially dangerous infrastructure and substances in urban areas tends to increase the physical vulnerability of urban populations. Furthermore, the presence of health-threatening infrastructure at such locations, such as sewage treatment plants or hazardous industries, increases the risk of secondary hazards and damage. Depending on the location of the flooding event, this type of risk can be classified as urban or non-urban. Socio-economic factors must therefore be given special consideration in the context of human settlement locations (Ozcan O., et al, 2010). Flood risk must be integrated into territorial management, such as in urban or municipal areas, which necessitates a better understanding of the associated vulnerabilities.

Most studies have used hydrologic and hydraulic models to simulate flood runoff and runoff in low-lying and flood-prone areas to provide flood risk assessment information on the probability of flood occurrence, the magnitude of the event, location, and depth of the inundation for flood management (Booij, M., 2005).

The technique for preparing flood hazard maps was presented by (Goel, N. et al., 2005), which included the development of a digital elevation model and simulation of flood flows of various return periods. In (Bhadra, A. et al., 2011), the authors proved that the GIS technique is effective in extracting the flood inundation extent in a time and cost-effective manner for the remotely located hilly basin of Dikrong, where conducting conventional surveys is very difficult. Furthermore, (Thilagavathi, G. et al., 2011) used GIS to divide the Papanasam Taluk's flood-prone areas into five zones with varying degrees of flooding. Moreover, (Orok, H., 2011) stated that a flood risk map should be able to identify the areas that are most vulnerable to flooding and estimate the number of people that will be affected by floods in a particular area. Because all disasters have a spatial component, it is necessary to have adequate geographic information on hazards and vulnerable areas to prepare for disasters. Since 80 per cent of data used by decision-makers is related to geography, multi-criteria evaluation (MCE) methods have been used in several studies (Malczewski, J., 1999). With the overlay process, GIS can provide more and better information about decision-making situations by allowing the decision-maker to identify and list a predefined set of criteria. GIS-based multi-criteria decision analysis can be used to develop and evaluate alternative plans that can help interested parties agree (Malczewski, J., 1999).

The main benefit of using GIS for flood analyses is that it not only creates a visual representation of flooding, but it also allows for further analysis of these events to estimate flood damage. GIS, as opposed to traditional mapping, allows for comparisons across spatial units, comparisons across different themes by category of hazards and disasters, and the merging of qualitative with qualitative assessment, as well as a spatial database on which logical and/or numerical operations can be performed dynamically. Because natural hazards are multi-dimensional phenomena with a spatial component, these are grounds for concluding that GIS has an important role to play in natural hazards analyses (Coppock, et al., 1995). Most traditional GIS-based flood risk mapping methods (Yalcin et al., 2002) are based on ground surveys and aerial observations, but such methods are time-consuming and expensive when the phenomenon is widespread. Furthermore, due to adverse weather conditions, timely aerial observations may be impossible. As a result of integrating the Analytical Hierarchical Process (AHP) as multi-criteria decision-making (MCDM) technique within a

GIS mapping environment, this study proposes a multi-parametric approach for delineating flood vulnerability in a growing urban area. AHP's effectiveness in evaluating problems involving multiple and diverse criteria, as well as the measurement of trade-offs often with limited data has led to its acceptance in a variety of fields (Ho, 2008).

Multi-criteria analysis methods provide a framework for identifying the elements of a complex decision problem, organizing the elements into a hierarchical structure, and studying the relationships between the problem's components (Boroushaki, et al., 2010). This method is still rarely used in the context of flood risk management (Brouwer, et al., 2004). Various flooding problems have been solved using AHP as an MCA approach. The authors of (Willet, et al., 1991) used AHP to choose the best flood control projects for the Grand River and Tar Creek in Miami, Florida. Flood risk analysis using AHP and GIS has been applied to the Kosi River Basin in India (Sinha, 2008). (Chen, 2004) used a two-dimensional diffusive overland flow model to simulate inundation status in northern Taiwan, and then used a geographic information system (GIS) to visualize the area and depth of inundation. They used grey AHP to develop a model based on the inundation map to assess the potential damage from floods. The flood index (Sinha, 2008) was created using AHP to rank the importance of loss of life and different properties (Chen, 2004). Using GIS, the total ranks of the index of possible damage were then mapped (Hapuarachchi, et al., 2011). According to the reviews above, AHP is mostly used in natural settings rather than in developed urban areas.

Floods put the problem of un-gauged area prediction in a very difficult situation. Because the dominant processes of runoff generation may change as storm severity increases, process understanding is required for flood risk management. As a result, an understanding based on moderate flood analysis may be questioned when used to forecast the response to extreme storms. This means that flood mapping in most developing countries, where data is scarce and decision-making is difficult, is a complicated problem that must account for data scarcity and uncertainty in the analysis and decision-making process. Most studies have focused on flood mitigation and management (Jonkman, et al., 2012), but there has been less research on pre-flood mapping.

This study uses the AHP-GIS approach to create a flood vulnerability map that is easy to read based on morphometric and topographic data.

CHAPTER THREE

3.0 Methodology

3.1 Description of Study Area

Ikpoba-Okha Local Government Area is one out of the three LGA residents within the Benin City metropolis which is also the capital of Edo State, Nigeria. Benin City is located within Latitude 6° 21’N and 6° 44’N and Longitude 5° 35’E and 5° 44’E. Benin City is situated on fairly flat land, about 8.5km above sea level so it is a flat terrain (Atedhor et al., 2011). It lies in the thick equatorial rainforest zone which experiences heavy rainfall. Benin City’s Population is 1,346,703 as of 2006 (National Population Census, 2006). The Ikpoba-Okha LGA where the study was carried out occupied an area extent of about 838.321 km^2 and has a population of 371,106 total population excluding the other two LGAs of Oredo and Egor.

The city is well-drained by two major rivers; the Ikpoba River which drains the Northeast of the city and the Ogba River which drains the southwest of the city. The vegetation is predominantly the evergreen rainforest but urban developments have drastically reduced the vegetation. Ikpoba River is a fourth-order stream situated within the rainforest belt of Edo State, Southern Nigeria (Efe, 2013).

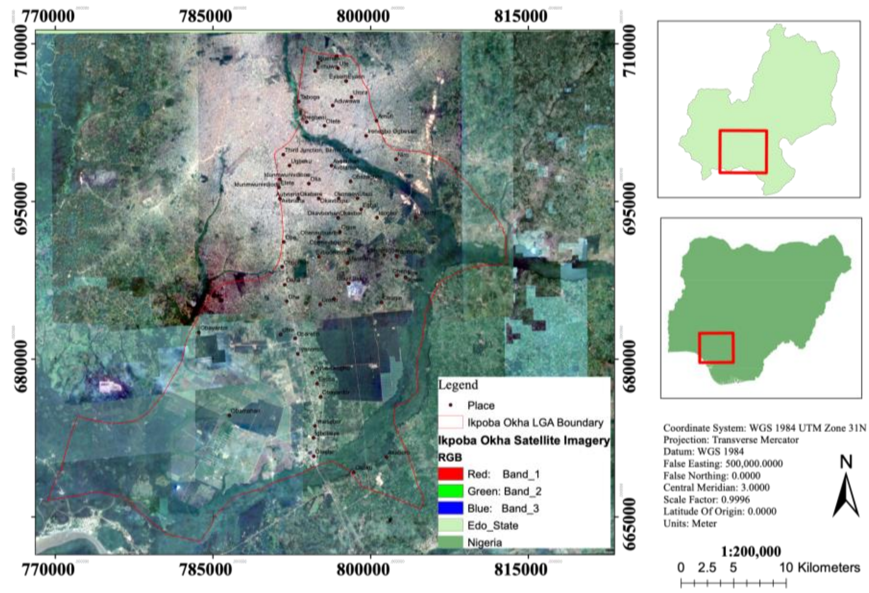

Figure 3.1: Study area map.

3.2. AHP Decision Hierarchical Structures Development

The fragmentation of a complex decision problem into smaller, more manageable pieces at multiple hierarchical levels/layers is referred to as a decision hierarchical structure. Figure 3.3 depicts a hierarchical tree with four levels. The objective or goal is at the top of the hierarchy, and the evaluation alternatives (options) are at the bottom, while the intermediate levels correspond to criteria and sub-criteria, depending on the project. Figure 3.4 shows a structure that is formed from the generalized notion seen in Figure 3.3.

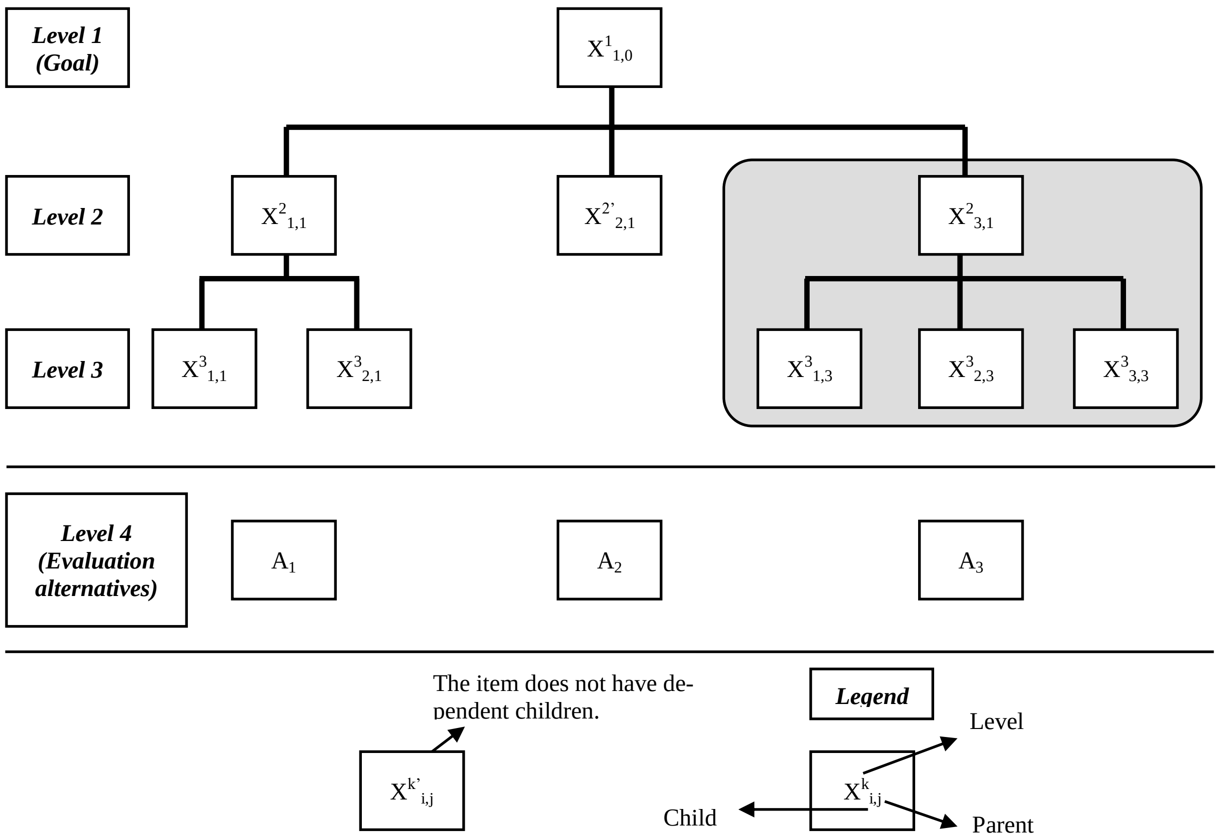

Figure 3.2: A four-level problem decomposition with a decision hierarchical structure.

Adapted from (Sadiq et al., 2004). Depending on the complexity of the criterion parts, the levels can be decreased to 3 or increased to 4.

The nomenclature used in Figure 3.4 for each item in the hierarchical model is Xki, j, where I am the child's order at level/layer k, and j is the child's parent (Sadiq, et al., 2004). For instance, X21,1 indicates that the item is at level k = 2, that it is the first child I = 1, and that its parent is j = 1. In the intermediate levels, each child is a criterion and sub-criterion that has an impact on the corresponding parent and child. Any intermediate item (element, factor, or sub-criterion) with an apostrophe, XK'I,j, indicates that the element has no dependent children. The derivation and discussion that follows are limited to the shaded items at levels 2 and 3. (i.e., X23,1, X31,3, X32,3, and X33,3).

To account for physical and socio-economic aspects in this case study, a three-level structure was used (Figure 3.5). These parameters are elevation from a digital elevation model (EL); slope estimated from a DEM (SP); land-use and land cover from a municipal zoning map (LU); rainfall (RF); soil types (SW); and stream or drainage networks (see Figure 3.5). (DN). In the analysis, the municipality boundary is employed as a constraint factor. When putting together an AHP hierarchy with a high number of pieces, the decision-maker should try to group them in clusters so that they don't diverge in extreme ways, as recommended by (Ishizaka, et al., 2011). AHP is utilized as a Multi-Criteria Decision Analysis (MCDA) in the multi-criteria decision-making process by arranging data in this way (Figure 3.5).

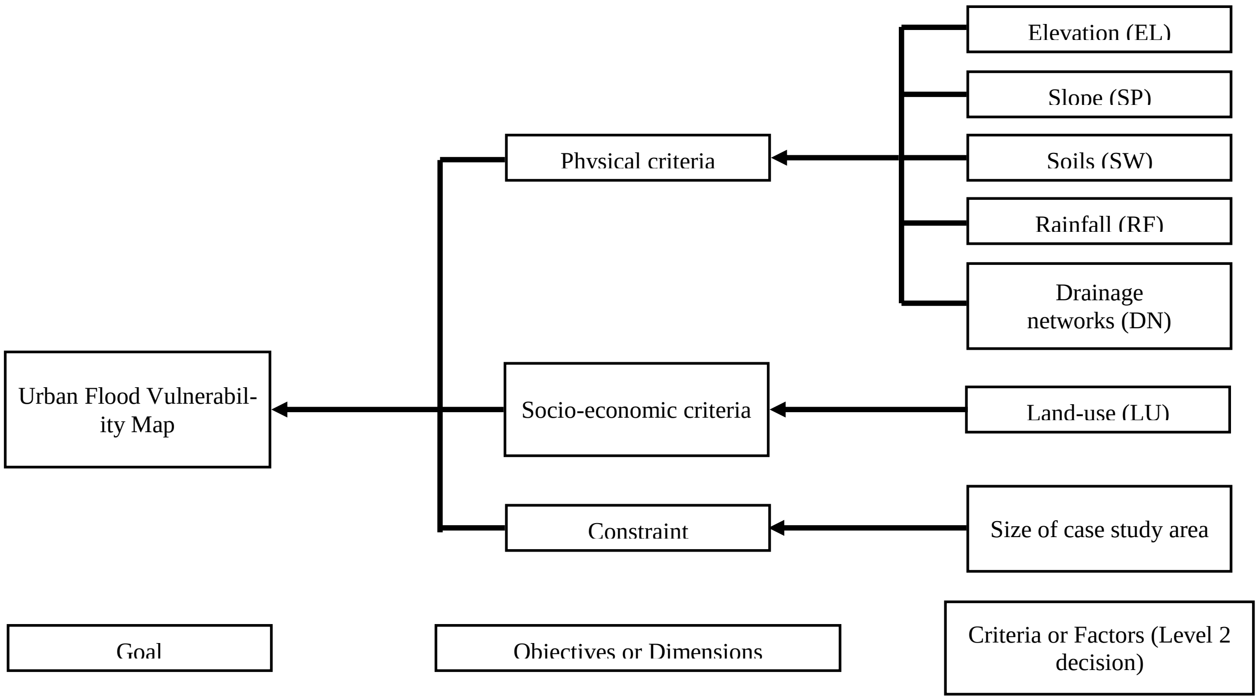

Figure 3.3 depicts urban flood vulnerability as a three-level hierarchical structure of parameter features

3.2.1 ANALYTICAL HIERARCHY PROCESS (AHP) as a Tool for Multi-Criteria Decision Making

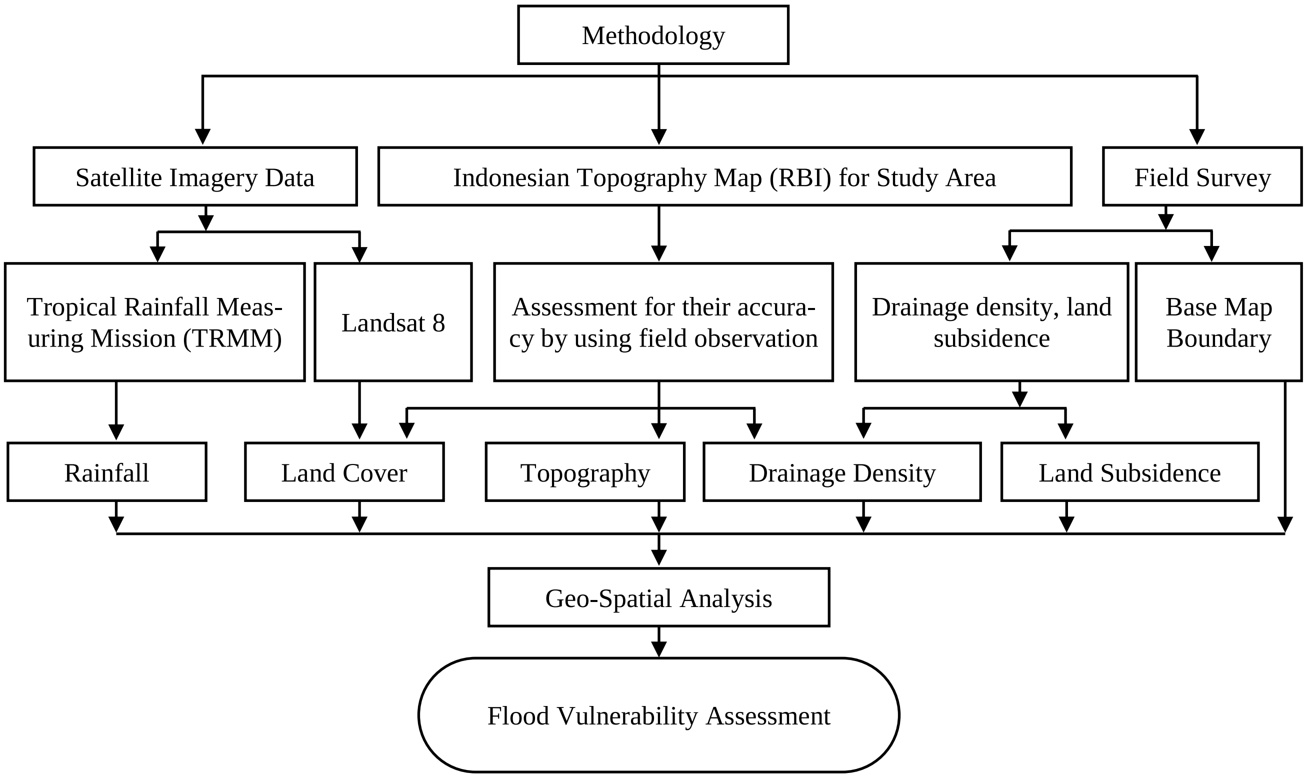

Figure 3.2: Research methodology

In most decision-making processes, the expert works with the decision-maker(s) to structure the problem appropriately. When allocating weights, AHP has the advantage of allowing a hierarchical structure of the criteria, which allows users to focus more on specific criteria and sub-criteria. This is critical because a different structure could result in a different final ranking. Criteria with a large number of sub-criteria are given more weight than those with fewer sub-criteria. The analytic hierarchy process, which is a structured technique for dealing with complex decisions, was used to structure the flood causative factors in the application of multi-criteria decision analysis.

In theory, rather than prescribing a proper solution, the AHP assists decision-makers in identifying the one that best meets their needs and understanding the problem. As a result, AHP is a decision-making strategy based on people's genuine ability to make key decisions. It enables decision-makers to actively participate in the exploration of all available choices to thoroughly comprehend the underlying challenges before reaching an agreement or making a decision (Estoque, et al., 2010). As a result, the goal of AHP is to evaluate the available options for a certain goal by establishing priorities for these options and the criteria that have been chosen.

A pairwise comparison technique is utilized in the AHP implementation to determine the priorities for the criteria in terms of their importance in attaining the aim. Similarly, the alternatives' priorities (i.e., the competing choices under consideration) are determined through pairwise evaluations of their performance against each criterion. As a result, AHP is founded on three principles: decomposition, comparison judgment, and priority synthesis (Saaty, 2008).

AHP provides an effective quantitative decision-making method for dealing with complicated and unstructured problems by arranging and assessing alternatives according to a hierarchy of multiple features, as shown in Figure 3.3. AHP provides a better, simpler, and more efficient framework for identifying selection criteria, calculating their weights, and analyzing the results (Bojovic, et al., 2008). As a result, the technique allows judgments on intangible qualitative factors to be combined with tangible quantitative criteria. The expert(s) and participants utilize AHP to establish priorities for all of the hierarchy's nodes once it has been established. By doing so, information from experts and participants is elicited and quantitatively processed. Priorities are allocated over a hierarchy based on the design, and their values are determined by the information submitted by process users, as shown in Table 1. Multiple pairwise comparisons in AHP are based on a nine-level standardized comparison scale (Table 1). The nine points were chosen because psychologists believe that nine objects are the maximum number of objects that an individual can compare and rank consistently. Pairwise decisions are made using the most up-to-date information and the decision maker's knowledge and experience.

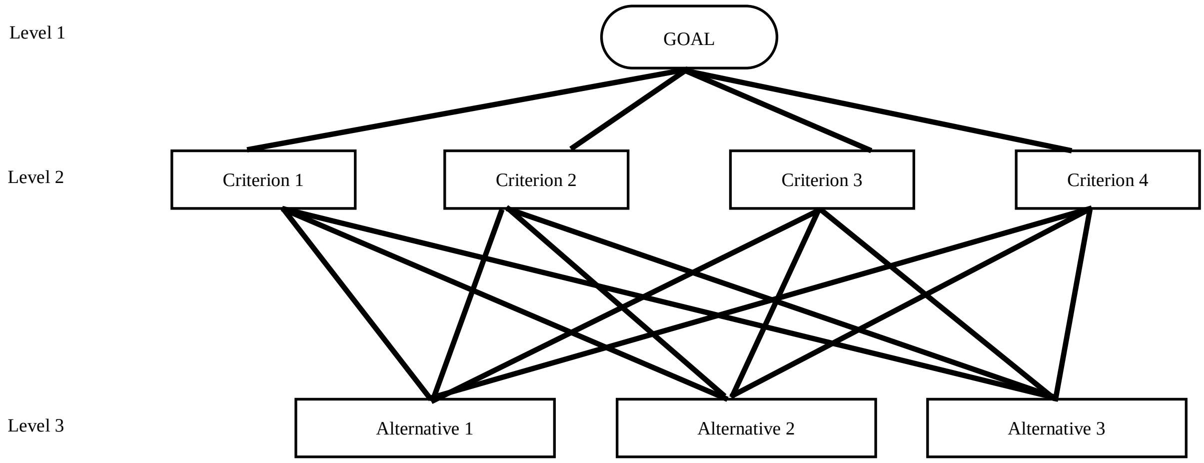

Figure 3.3: The general structure of the analytical hierarchy process (AHP) for multi-criteria decision-making.

modified from (Zahedi, 1986).

The goal is to choose among the competing alternatives 1, 2, and 3 based on a ranking score when judged individually against criteria 1, 2, 3, and 4.

Table 1. The nine-point intensity of importance scale was modified from (Schoenherr, 2008).

Intensity of importance	Definition	Description
1	Equally important	Two factors contribute equally to the objective.
3	Moderately more important	Experiences and judgment slightly favour one over the other
5	Strongly more important	Experiences and judgment strongly favour one over the other
7	Very strong more important	Experiences and judgment very strongly favour one over the other. Its importance is demonstrated in practice.
9	Extremely more important	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed
Reciprocals of above	If any element *I* have one of the above numbers assigned to it when compared with element *j*, then *j* has the reciprocal value when compared with *i*	-
Ratios (1.1-1.9)	If the activities (elements) are very close	May be difficult to assign the best value, but when compared with other contrasting activities (elements) the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities (elements).

The basic stages of AHP are to build the decision hierarchy, assess the relative relevance of attributes and sub-attributes, evaluate each option and calculate its total weight for each attribute, and confirm the consistency of subjective evaluations (Schoenherr et al., 2008). The choice was then broken down into its constituent parts and depicted in a hierarchy diagram with at least three levels (goal, qualities, and options) (Figure 3.3). Second, the user is asked to rate pairs of traits on a range of one to nine. Based on the paired comparisons, a weight is calculated for each attribute (and sub-attribute) in the third stage. Because the user's judgments are subjective, the logical consistency of these assessments is tested in the final stage. The AHP produces a relative score for each decision alternative, which can be used in the decision-making process that follows. As detailed, AHP has been successfully employed in a variety of subjects and disciplines (Ishizaka, et al., 2011). AHP is an ideal methodology for some priority problems by considering different criteria because it can handle both qualitative and quantitative data. This is shown mathematically below.

The set of criteria is C = Cj | j = 1, 2, ..., n. The result of the pairwise comparison on n criteria can be described in a_ n) evaluation matrix A, where each member aij (i, j = 1,2, ..., n) is the quotient of the criteria's weights, as shown in Equation 3.1. $A = \begin{bmatrix} a_{11} & a_{12}. & a_{1n} \\ a_{21} & a_{22}. & a_{2n} \\ a_{n1} & a_{n2}. & a_{nn} \end{bmatrix}, a_{ii} = 1, a_{ji} = {}^{1}/_{a_{ij}}, a_{ij} \neq 0$ (3.1)

The mathematical process to normalize and calculate the relative weights for each matrix begins at the end of AHP. The right eigenvector determines the relative weights (w) corresponding to the largest eigenvalue (λ_{max}) as in Equation (3.2).

$$A_w = \lambda_{max} W \quad (3.2)$$

The matrix A has rank 1 and λmax = n if the pairwise comparisons are consistent. Weights can be obtained in this scenario by normalizing any of A's rows or columns (Wang, et al., 2007). It should be emphasized that the consistency of the pairwise comparison assessments is directly related to the quality of the AHP's output.

The relationship between the entries of A defines the consistency: aij x ajk = aik.

Equation (3.3) gives the consistency index CI:

$CI=(\lambda_{max} - n) / (n - 1)$ (3.3)

The final consistency ratio (CR), the usage of which lets the user conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the random index (RI), as expressed in Equation (3.4). The values of RI are tabulated in Table 2.

$$CR = CI/RI \quad (3.4)$$

The maximum threshold of the CR is 10%, and in case of exceedance a three-step procedure is followed (Saaty, 2008): (i) identify the most inconsistent judgment in the decision matrix; (ii) determine a range of values the inconsistent judgment can be changed to so that would reduce the associated inconsistency; and (iii) ask the decision-maker to reconsider the judgment to a "reasonable value".

N	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 2. Random index (RI) is used to compute consistency ratios (CR).

The random index in Table 2 is obtained by averaging the CI of a randomly generated reciprocal matrix (Saaty, 2008). The measurement of consistency can be used to evaluate the consistency of decision-makers as well as the consistency of the overall hierarchy (Wang, et al., 2007). The AHP steps listed above can be broken down into five basic steps: (Estoque, 2012).

Step 1: Creating a problem model

The first phase entails describing the problem, widening the problem's objectives by taking into account all actors, objectives, and consequences, and identifying decision factors such as alternatives, criteria, and decision rules. The aim, criterion, sub-criteria, and alternatives are organized into a hierarchical structure of interconnected decision factors (Vaidya, et al., 2006). This stage has long been regarded as the most crucial in AHP (Zahedi, 1986). The general goal (i.e., level 1), such as picking the best choice, is at the very top of the hierarchy. The decision rules or criteria that contribute to the achievement of the overall aim are found at the next lower level (i.e., level 2) of the hierarchy. Depending on how much information is evaluated for each decision rule or criterion, this level can be enhanced. The alternative decisions that the decision analyst/maker will choose are found at the lowest level (i.e. level 3). Figure 3.3 depicts a simplified general structure of the AHP.

Step 2: Establishing Priorities Among the Hierarchy's Decision Elements

This stage entails utilizing a pairwise comparison technique and a rating scale of relative relevance to collect ratings for each of the criteria and options. This stage enlists the help of experts and/or stakeholders in establishing the relative relevance of one criterion or option over another using a matrix-based pairwise comparison method (Saaty, 2008). (Number of comparisons = n (n – 1)/2) is used to calculate the number of comparisons for decision elements (i.e., criteria or alternatives) in a given level (Teknomo, 2013). A group of experts rates each comparison (e.g., Criteria 1 vs. Criteria 2 or Alternative 1 vs. Alternative 2) using the scale devised by (Saaty, 2008) for a pairwise comparison technique (Table 1). A questionnaire for comparing all parts and a geometric mean to arrive at a final solution is usually included in the process to integrate group consensus (Teknomo, 2013).

Step 3: Calculating the Decision Elements' Overall Relative Weights

After preparing a pairwise comparison matrix for the criteria and the alternatives, this phase determines the relative relevance of the criteria in terms of achieving the goal, as well as the relative importance of the alternatives for the criteria (Step 2). This is accomplished by obtaining the normalized primary eigenvectors or priority vectors for each criterion and alternative, and (ii) calculating the normalized values for each criterion and alternative (herein also referred to as relative weights). The value for each cell is divided by the column total when calculating the normalized values for each criterion and alternative in their associated matrices. For each criterion and alternative, this approach results in a column total of 1. After then, the relative weights are derived by averaging each matrix's rows. The resulting numbers are the relative weights of the goal's criterion, as well as the relative weights of the criteria's alternatives. Calculating the linear combination (LC) of the product between the relative weight of each criterion and the relative weight of the alternative for that criterion yields the overall relative weights of the alternatives (Teknomo, 2013). If the expert judgments are similar (see Steps 4 and 5), the decision-makers will choose the best option based on the overall relative weights of the options.

Steps 4 and 5: Consistency Test.

Before making a judgment, these steps are required to determine the consistency of the evaluation by computing the consistency ratio. If the goal of the task is to find the best option, the CRs for all of the matrices (i.e., the criteria and the alternatives) are computed first, followed by the overall relative weights of the alternatives. For each criterion/alternative, calculate the greatest eigenvalue, consistency index, consistency ratio, and normalized values.

In addition, (Saaty, 1980). If the ratio is more than 0.1, the set of judgments may be too inconsistent to be trusted. As a result, a CR of less than 0.1 per cent or 10% is acceptable. When the results are inconclusive, the operation is repeated until the CR falls within the target range. Following that, decision-makers draw a conclusion based on the findings.

CHAPTER FOUR

4.0 Results and Discussions

All maps produced are in WGS84 UTM Zone 31 N coordinate system.

4.1 Result:

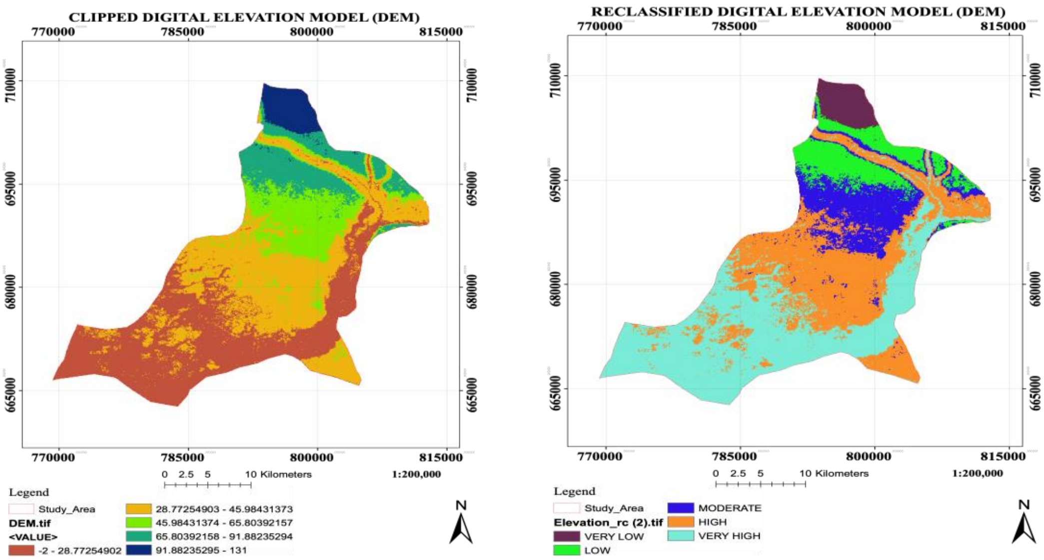

Figure 4.1: Original DEM Map, Reclassified DEM Map

Procedure for the above Map

Digital Elevation Model (DEM) was downloaded from the United States Geological Survey (USGS) website https://earthexplorer.usgs.gov and input into the ArcGIS environment,

The shapefile of the study area which was created earlier was added to ArcGIS,

A function "clip Raster" was used to clip the DEM into the desired shape,

And "Reclassify" function was used to reclassify the DEM based on elevation level into five(5) group which was named: Very High, High, Moderate, Low, and Very Low respectively.

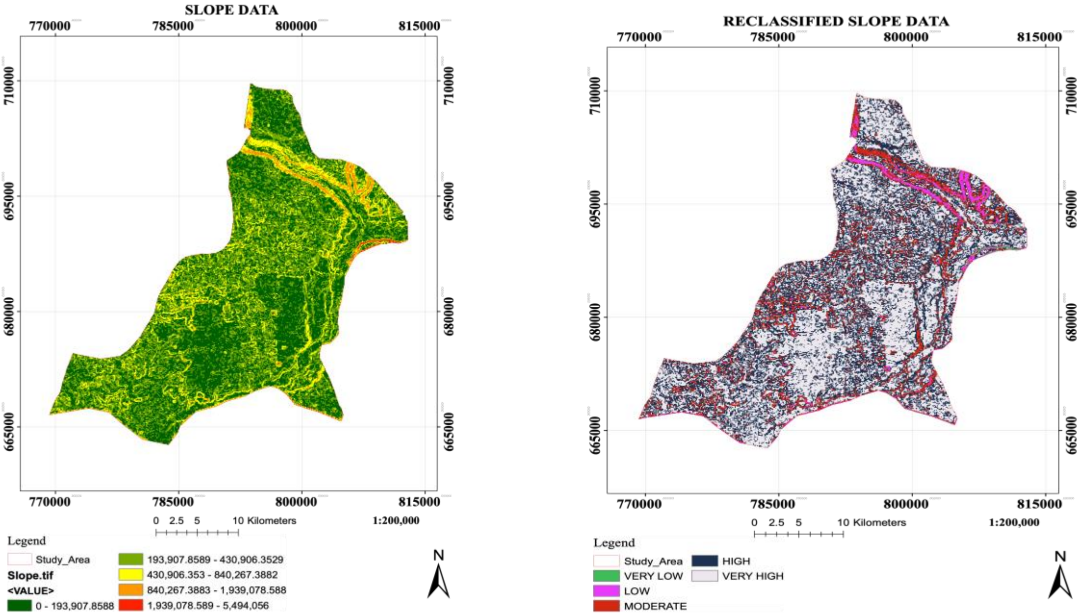

Figure 4.2: Slope Map, Reclassified Slope Map.

Procedure for the above Map

A slope map was created from the DEM layer.

From ArcGIS System Toolboxes > Spatial Analyst Tools > Surface > Slope.

The output of the Topo to Raster tool is the input raster. The location of the output raster was specified. The output measurement was measured.

Click OK. A slope map is created from the DEM layer.

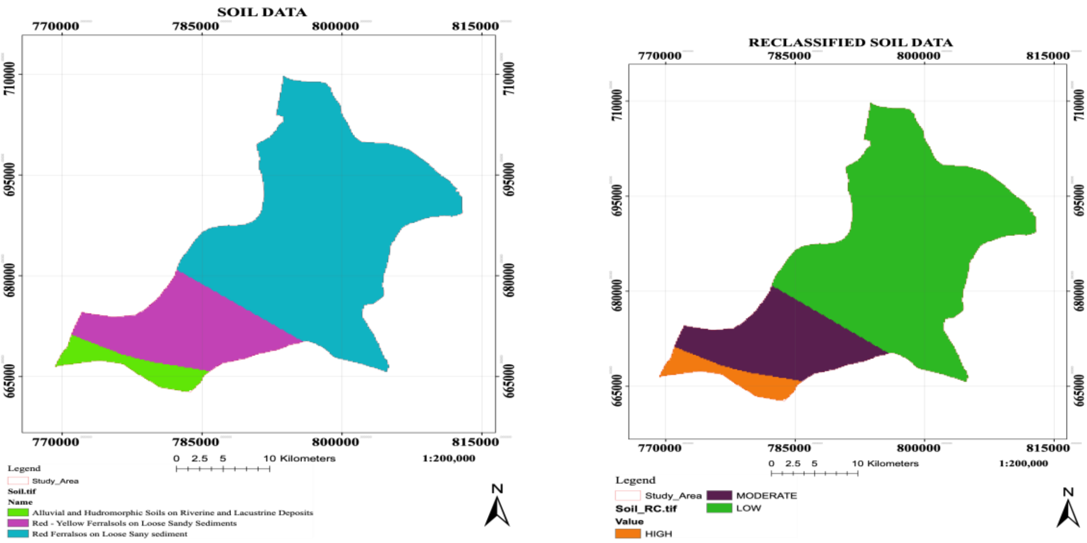

Figure 4.3: Soil Data Map, The Reclassified Soil Map

Procedure for the above Map

A scanned image of the soil map of Nigeria was georeferenced and digitized.

The study area layer was then used to clip the vector layer(digitized soil map) And the vector soil map was then converted to raster, using the “Polygon to raster” feature in ArcGIS.

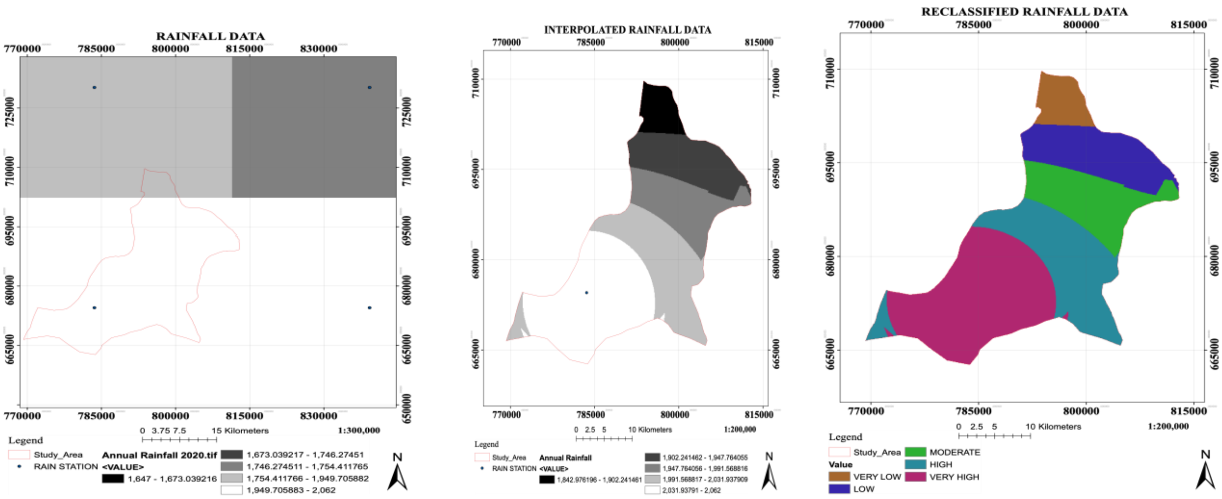

Figure 4.4: Rainfall Data Map, Interpolation Rainfall Data Map, Reclassified Rainfall Data Map

Procedure for the above Map

Rainfall data was downloaded and interpolated using the inverse distance weighting (IDW) method for it.

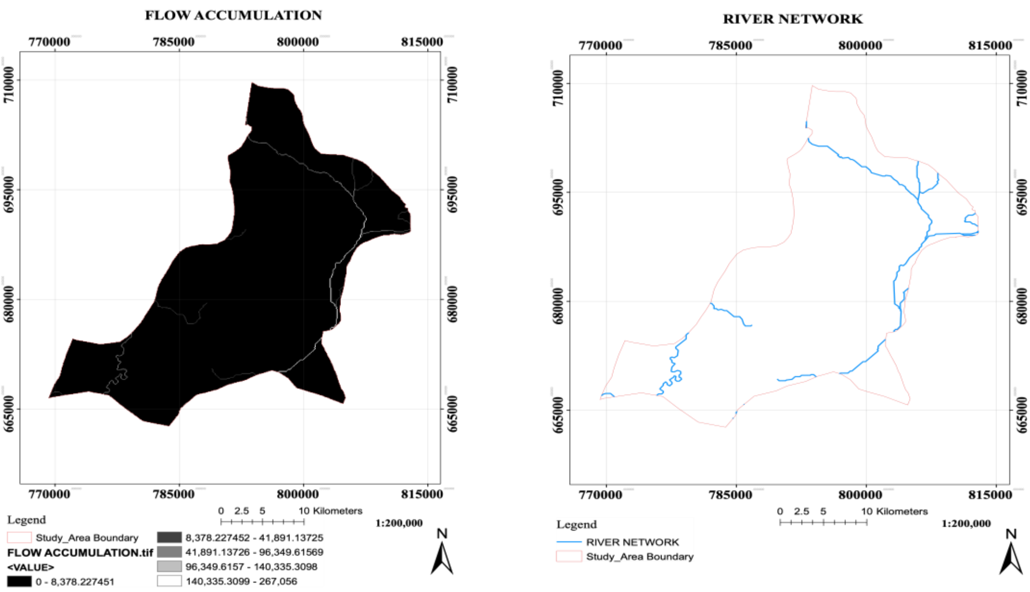

Figure 4.5: Flow Accumulation Map, River Network Map

Procedure for the above Map

Add DEM Map in ArcMap Software, then open ArcToolbox.

Already open ArcToolbox, select Spatial Analyst Tool > Hydrology, and perform 3 tasks one by one – (i) Fill, (ii) Flow Direction, and (iii) Flow Accumulation.

(i) Fill

Open Fill, select Input file- Dem Map, choose Output Destination and write the name, then click OK.

(ii) Flow Direction

Open Flow Direction, select Input file- Fill, choose Output Destination and write the name, then click OK.

(iii) Flow Accumulation

Open Flow Accumulation, select Input file- Flow Direction, choose Output Destination and write the name, then click OK.

Complete all 3 processes, Now open the Raster calculator to calculate Flow Accumulation.

Open the Search Box and search Raster Calculator. Raster Calculator window appears, double click Flow Accumulation Data (FLOW_ACCU) >=5000 (this value calculate for River Accumulation). Write-Output name and choose a destination and then click the OK Button.

You can see the calculated Flow Accumulation Result (flow_accu_cal) ‘0’ and ‘1’. Value 1 mentions River Network.

Customize this Data to better understand River Network. Select flow_accu_cal data, Right-click, and choose Properties. Properties window appears value ‘0’ choose to blank colour and click OK.

Stream Order

The next step is to perform the Stream Order. Open ArcTollbox > select Spatial Analyst Tool > Hydrology > Stream Order.

Stream Order window appears, Input stream raster – Flow Accumulation Calculate Data (flow_accu_cal). Input flow direction raster – Flow Direction Data and then choose Output and click OK.

The next important part converts Stream ordering into a Feature as well as Polyline Shapefile.

In the ArcTollbox > select Spatial Analyst Tool > Hydrology > select Stream to Feature.

Stream to Feature window appears, Input stream raster (streamj_order), then Input flow direction raster (FLOW_DIRECT) and choose Output and click OK.

Customize Stream Network Feature Data, Right-click, and select Properties.

Stream Network Properties window appears, in the symbology group select Categories and choose GRID_CODE in the Value field option, and click Add all values.

You can also change colour, width, and Labels to Better Understand Stream Ordering. Complete all of the Processes click the OK button.

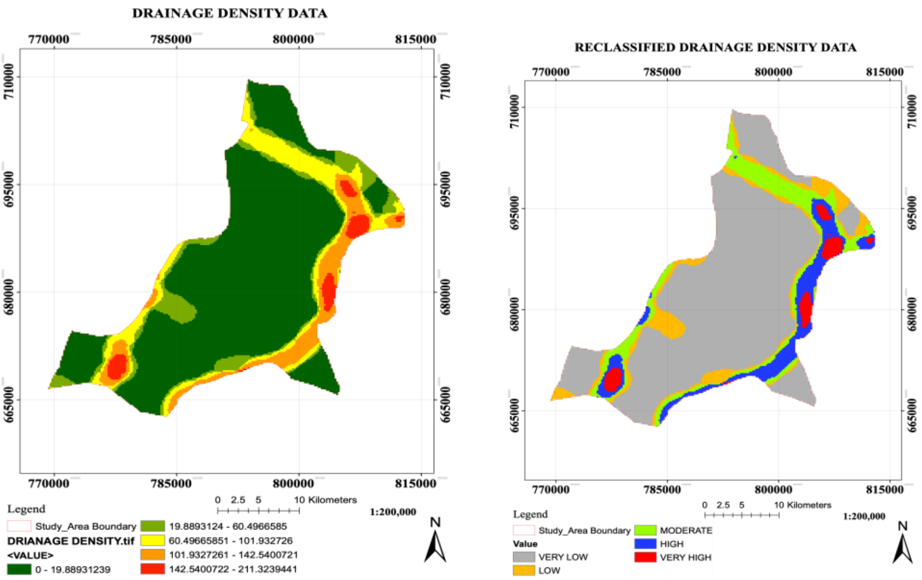

Figure 4.6. Drainage Density Data, Reclassified Drainage Density Data

Procedure for the above Map

From the ArcGIS software, input the DEM of the study area and search “line density” input the necessary parameters, and press Ok. The drainage density of the area will appear

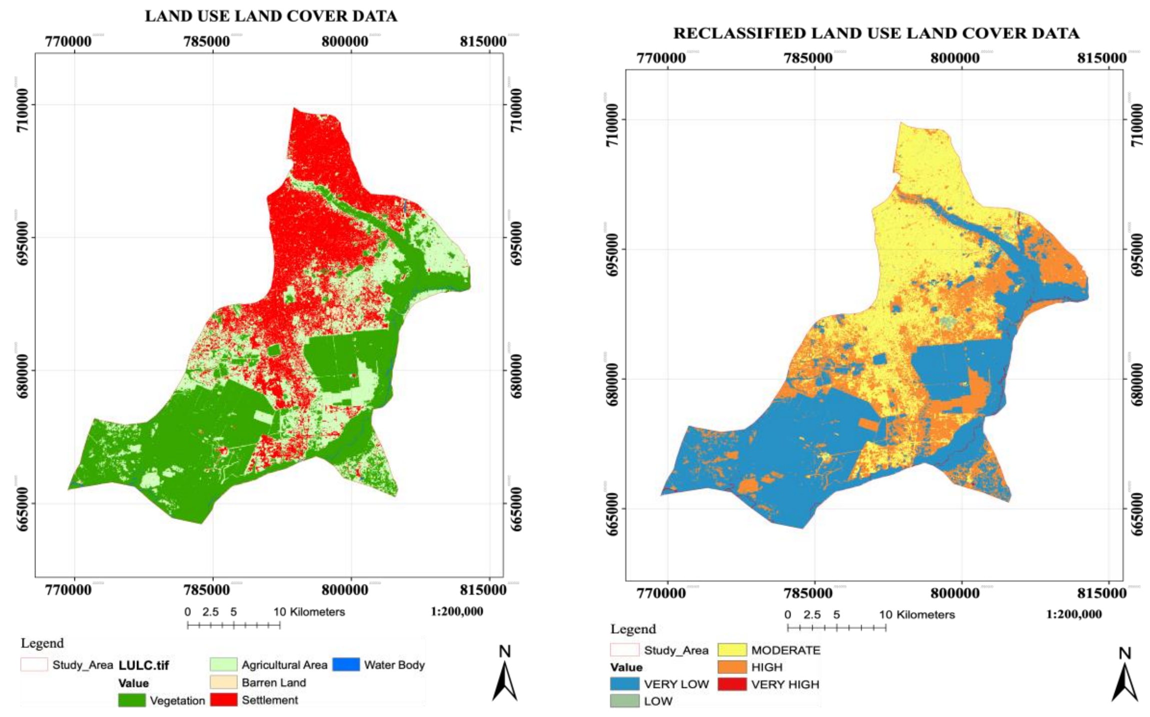

Figure 4.7: (N) Land Use Land Cover Map, (O) Reclassified Land Use Land Cover Map

Procedure for the above Map

i. Data Gathering

The data are satellite imageries (Landsat 8) of the research region downloaded from the United States Geological Survey for the year 2020. (USGS).

ii. Satellite images will be imported.

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

The following are the steps for combining the different bands into a single multispectral layer (colour 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 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) will be extracted from the whole satellite scene. This will be done by using the shape file contained in the boundary layer of the study area obtained for the study. This will then be used to sub-map the area of interest from all the bands on the images imported. This will be used to ensure the data quantity reduction and for focusing on the area of interest. The process (in ArcGIS; subsetting) will be repeated until all the bands are subsettled.

The steps in the image subsetting 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 includes bare surface, built-up area, rocks, and vegetation.

v. **Colour Composite**

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

a) Go to windows on the toolbar.

b) Click on image analysis (already the single bands were brought to the ArcGIS environment then add them to have a single multispectral band).

c) 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 will be created. The domain classes such as; bare surface, built-up areas, rocks, and vegetation will also be created. The steps below show how to create training samples using the controls on the toolbar:

a) On the toolbar, choose an appropriate image layer in the layer list.

b) Click the draw button. Notice that there are three drawing tools available, polygons, circles, and rectangles.

c) In the map display, identify an area that belongs to a known class. Use the drawing tools to define training samples.

d) 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 will be identified are; Built-up areas, bare surfaces, vegetation, and rocks. Image classification and analysis operations will be used to digitally identify and classify pixels in the data.

viii. **Classification Processes**

This will be 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;

a) The first step is to activate the spatial analysis extension in ArcGIS (customize> extensions>spatial analyst).

b) Generate clusters: this unsupervised classification example uses the iso-clusters unsupervised classification method (spatial analysis tools>multivariate>iso-clusters).

c) The next step was naming and selecting colours for each class that was generated by the iso-clusters output.

ix. **Post Classification Comparison**

In post-classification, the image of 2020 will be used to see the changes that occur within these periods. The classified image will then run for post-classification comparison to produce a change detection analysis. By using the change detection statistical tool of the post-classification, the matrix table of the ‘‘from –to’’ change class will be obtain obtained.

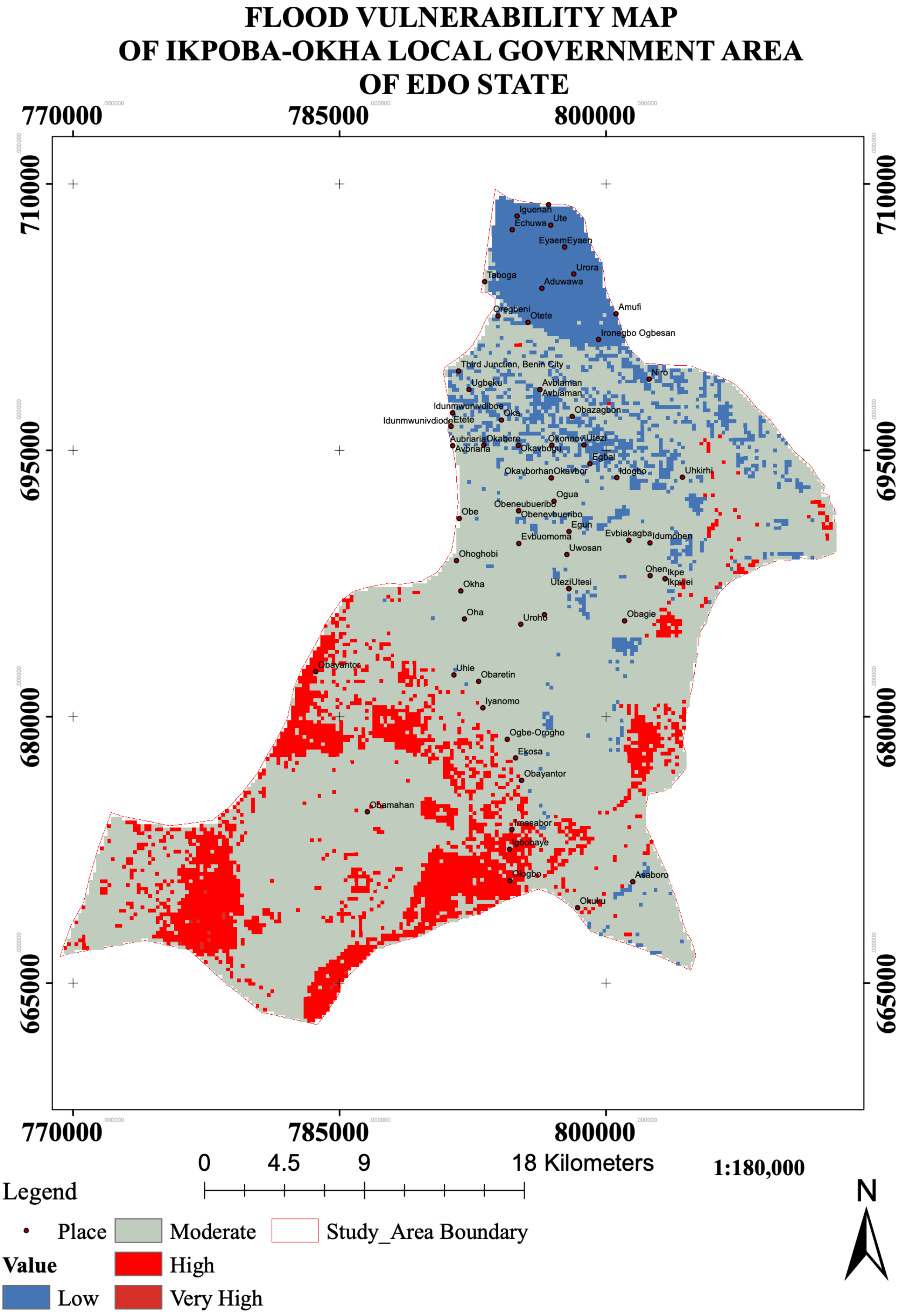

Figure 4.8: Flood Hazard Map

From the result above it is observed that the Ikpoba river area has a high vulnerability to flooding than other areas because it is a major river channel where all upland soil is been washed by erosion. Or you can explain it by saying the area toward the northern part of the map is less vulnerable compared to the southern part.

4.1.1 Criteria for Flood Mapping Ranking

The basic goal of AHP-based multi-criteria decision-making is to rank and prioritize options. The effectiveness of available resources, which is, in most situations, the primary assessment of the decision-maker, is directly influenced by the quality of priority-setting. Hydrologists and engineers commonly rely on heuristic and experiential assessments from the public, who are the end-users, when making decisions.

In this study, sixteen experts were asked to give their assessments and judgments regarding the variables related to flooding and their significance in terms of weights, out of the six factors analyzed, to determine the objectives and formulate the decision-making process. The experts included four hydrologists, four engineers, and eight end-users. End-users are those who are affected by the phenomenon and are represented in this case study by representatives from community leaders, the area chief, and the sub-chief. Experts or decision-makers are those who have the technical skills and know-how to solve a given problem, whereas end-users are those who are affected by the phenomenon and are represented in this case study by representatives from community leaders, area chiefs, and sub-chief. In three rounds, each expert participant assigned weights to the objective elements, each round using a different approach and consisting of the following rounds:

Round 1: Assign each aim or factor percentage to reflect its weight.

Round 2: Assume the relevance scale among the objectives is linear, and use round 1 to identify the lowest priority.

Round 3: Objectives should be graded on a scale of one to five, with one being the least significant and five being the most important.

The eigenvector is used to weigh the standardized raster layers to highlight the importance of each element in comparison to the other criteria in the resulting flood hazard. Table 3 shows the results of the pairwise comparison and ranking of the criterion. Table 4 shows the normalized matrix transformed to per cent contributions and Table 5 shows the consistency of the matrix which was used to compute $\lambda_{max.}$

Table 3: Ranking of urban flood-causing criteria.

Ranking of Flood Vulnerability Parameters						
Criteria	Land-use	Rainfall	Drainage	Elevation	Slope	Soil
Land-use	1	1	2	2	1	1
Rainfall	1	1	1	1	1	2
Drainage	0.5	1	1	2	1	1
Elevation	0.5	1	0.5	1	2	2
Slope	1	1	1	0.5	1	1
Soil	1	0.5	1	0.5	1	1
Total	5	5.5	6.5	7	7	8

Table 4: Normalizing the criteria columns to obtain the normalized matrix.

Criteria	**Land-use**	**Rainfall**	**Drainage**	**Elevation**	**Slope**	**Soil**	**Criteria Weight**	**Per cent (%)**
Land-use	0.200	0.182	0.308	0.286	0.143	0.125	0.207	21
Rainfall	0.200	0.182	0.154	0.143	0.143	0.250	0.179	18
Drainage	0.100	0.182	0.154	0.286	0.143	0.125	0.165	16
Elevation	0.100	0.182	0.077	0.143	0.286	0.250	0.173	17
Slope	0.200	0.182	0.154	0.071	0.143	0.125	0.146	15
Soil	0.200	0.091	0.154	0.071	0.143	0.125	0.131	13
Total	1	1	1	1	1	1	1	100

Table 5. Calculating the Consistency of the criteria columns to obtain the λ_{max}.

Consistency Matrix									
Criteria	Land use	Rainfall	Drainage	Elevation	Slope	Soil	Weighted Sum Value	Criteria Weight	
Land-use	0.207	0.179	0.330	0.346	0.146	0.131	1.338	0.207	6.5
Rainfall	0.207	0.179	0.165	0.173	0.146	0.261	1.131	0.179	6.3
Drainage	0.104	0.179	0.165	0.346	0.146	0.131	1.069	0.165	6.5
Elevation	0.104	0.179	0.082	0.173	0.292	0.261	1.090	0.173	6.3
Slope	0.207	0.179	0.165	0.086	0.146	0.131	0.914	0.146	6.3
Soil	0.207	0.089	0.165	0.086	0.131	0.131	0.809	0.131	6.2

From Table 5,

A consistency Index (CI) of 0.07 and a Random Index (RI) for 6 (Six) parameter computations yielded a final value of 1.24. The maximum permitted values for CI and RI are 0.1 and 10%, respectively. The CI and CR values in this investigation were 0.07 (CI 0.1) and 5.5 per cent (CR 10 per cent, respectively, to ensure that they met the highest criteria allowed. These are the values:

Table 6: Weighted flood hazard Values.

N		**6**
Lambda (λ_{max})	(6.5+6.3+6.5+6.3+6.3+6.2)/6	6.3
CI	$(\lambda_{max}$-n)/(n-1)	0.07
RI		1.24
CR	CI/RI	0.055
CR%		5.5

Once the relative importance of each element had been established, a multi-criteria analysis was carried out using a GIS technique to create a flood-vulnerable region.

The results of flood vulnerability mapping in the Study Area are shown in Figure 4.8. The vulnerability of flood areas is categorized into 5 (five) criteria, namely "Very high vulnerable", "High vulnerable", "Moderate vulnerable", “Low vulnerable”, and “Very low vulnerable”.

4.1.2 Model Input Factors Weighting and Ranking

The pairwise comparison matrix and the factor maps are employed in the weight and ranking computation stage. To obtain the best fit to the weight set, the primary eigenvector of the pairwise comparison matrix is calculated. Priorities are represented by weight values, which are absolute numbers between zero and one. When using a weighted linear combination, the weights must add up to one. Table 5 shows a summary of the flood causative factors or variables development, including the numerous components, their relative weights, and how they are placed in terms of their influence on flood episodes in the research area. The sub-factors (j) in Table 5 are the deciding factor I ranges that contribute to the choice ranking values. Table 5 shows how the three-level hierarchical structure is divided, as well as how the ranking decision for vulnerability and risk mapping is made.

The factors with a greater weight value have higher importance or impact in the study than those with a lower weight value. The soil cover, which is characterized by infiltration, has the highest weights, meaning that it contributes more to flooding in the area than the other components or elements, according to the factor weights identified for this study area. This component has an impact not only on the bare soil surfaces but also on the overall material that covers an area.

Table 7: Weighted flood hazard ranking for the case study.

Parameter	Relative Weight (%)	Reclassified Parameter	Ranking
Urban land-use	21	Vegetation Barren Land Settlement Agricultural Area Water Body	1 2 3 4 5
Rainfall (mm)	18	1,842.976196 - 1,902.241461 1,902.241462 - 1,947.764055 1,947.764056 - 1,991.568816 1,991.568817 - 2,031.937909 2,031.93791 - 2,062	1 2 3 4 5
Drainage density (km/km^2)	16	0 - 19.88931239 19.8893124 - 60.4966585 60.49665851 - 101.932726 101.9327261 - 142.5400721 142.5400722 - 211.3239441	1 2 3 4 5
Elevation (meters)	17	-2 - 28.77254902 28.77254903 - 45.98431373 45.98431374 - 65.80392157 65.80392158 - 91.88235294 91.88235295 – 131	5 4 3 2 1
Slope (degrees)	15	0 - 193,907.8588 193,907.8589 - 430,906.3529 430,906.353 - 840,267.3882 840,267.3883 - 1,939,078.588 1,939,078.589 - 5,494,056	5 4 3 2 1
Soil classes	13	1373 5746 19599	4 3 2

4.2 Discussion

4.2.1 Discussion of the Results (Variables and Analysis for Flood Vulnerability Mapping)

The morphometric and topographic features, as well as variables analysis, are presented in this section as factors in the construction of AHP-GIS decision-making. The flood type, in particular, significantly impacts the variables used for the multi-parametric AHP. This section discusses the factors utilized in the vulnerability analysis and their classification into risk classes and importance levels (Table 1). In multi-criteria decision analysis, selecting criteria with a spatial reference is a crucial and significant stage. As a result, the criteria used in this study were chosen based on their importance in creating floods in the study area. Elevation and slope, as well as soil types, yearly rainfall distribution, drainage density, and land-use/land-cover information, are all taken into account.

i. **Slope and Elevation**

Elevation and slope are essential factors in determining a terrain's stability. The slope influences the direction and volume of surface runoff or subsurface drainage that reaches a place. The slope has a significant impact on the amount of rainfall that contributes to streamflow. It regulates the length of time that overland flow, infiltration, and subsurface flow last. The shape of the slope and its link to lithology, structure, soil type, and drainage is determined by a combination of slope angles. A smooth/flat surface that allows water to flow quickly is a disadvantage and can lead to flooding, but a higher surface roughness can reduce the flood response. Surface runoff is more likely on steeper slopes while waterlogging is more likely on flat land. In comparison to high-gradient slopes, low-gradient slopes are extremely sensitive to flooding. Rain or extra river water always collects in a region with a low slope gradient. Water does not collect in areas with steep slope gradients, resulting in flooding. If the main worry is a river-caused flood, the elevation difference between the various DEM cells from the river may be examined, but local depressions, i.e., DEM cells with lower elevation than the surrounding ones, would be more essential for pluvial floods. This means that how elevation is linked to danger is critical.

This study created the slope map using ArcGIS software's digital elevation model (DEM) and slope creation capabilities. Because of the nearly flat terrain, slope classes with fewer values were given a higher rank, while those with the highest value were given a lower rank due to the comparatively large run-off.

Figure 4.1 & 4.2 depicts the findings of the case study's original and reclassified elevation and slope layers. According to Figure 4.2, the entire study area is on a moderately steep slope. This suggests that slope may not be the most important factor in determining the order of hazard and risk classes.

ii Type of Soil

The most significant components and features of soils are texture and wetness. Because sandy soil absorbs water quickly and produces little runoff, soil textures have a significant impact on flooding. Clay soils, on the other hand, are less porous and hold water for longer than sandy soils. This means that locations with clay soils are more susceptible to flooding. When no measurements are available, soil moisture can be inferred based on the feel and appearance of the soil. It serves as a barrier between the land surface and the atmosphere, allowing precipitation to be partitioned into runoff and groundwater storage. Soil moisture levels rise when rainfall exceeds losses to streams and groundwater, and it is vital for soil erosion, slope stability, plant and agricultural growth, and slope stability. The soil types in an area are essential in general because they affect the quantity of water that may permeate into the ground and, as a result, the amount of water that flows (Nicholls, 1990). Soil structure and infiltration capacity will have a significant impact on the soil's ability to behave like a sponge and absorb water. Soil capacity varies depending on the kind of soil. A decrease in soil infiltration capacity, which produces an increase in surface runoff, raises the risk of flooding. When water is provided at a rate that exceeds the soil's capacity for infiltration, it flows downslope as runoff on sloping ground, causing flooding (Lowery, et al., 1996).

The soil map was classed based on infiltration capability for this case study. The municipality's soil types were divided into three categories: highly infiltrated, moderately penetrated, and less infiltrated soils. The study area's soil data was then vectorized into five infiltration classes, with the results indicating that clay-loam soils make up the majority of the study area's soils. Five raster data groups were created from the infiltration classes. The weighted soil map was created by giving weights to each soil class, with the soil type having the most potential to generate a high flood rate being ranked 5 and the one with the lowest capacity being ranked 1. Figure 4.3 shows the results of the soil factor in the research region.

iii Distribution of Rainfall

Floods are caused by a variety of factors, including heavy rainfall. Flooding is most typically caused by severe rains when natural watercourses are unable to transport the surplus water. Floods are caused by extremes in rainfall, and any water that does not penetrate the earth instantly runs downslope as runoff. The amount of runoff is proportional to the amount of rain that falls in a certain area. Heavy rains cause the amount of water in rivers and lakes to rise. When water levels rise over river banks or dams, the water begins to overflow, resulting in river-based floods. Floods or deluges occur when water from rivers, lakes, or dam’s overflows onto areas adjacent to them.

While local rainfall is important for pluvial flooding, rainfall amounts in upstream catchments contribute to flooding dangers and risks generated by rivers. Because of the small size of the study regions, both local and upstream rainfalls were included in the analysis. The generated raster layer was then categorized using an equal interval into the five classifications. The reclassified rainfall was assigned a value ranging from 1 to 5, with 1 being the least rainfall and 5 representing the most rainfall. The results of the raster rainfall layer, IDW interpolated data layer and classed rainfall data are shown in Figure 4.4.

iv Density of Drainage

Because its concentrations indicate the nature of the soil and its geotechnical properties, drainage is a key ecosystem for controlling dangers. This indicates that the higher the population density, the more sensitive the catchment region is to erosion, resulting in sedimentation on the lower grounds. The assignment of stream order is the first stage in the quantitative hazard analysis. The approach described was used to order the streams in the current study region (Strahler, 1964). The drainage map could be used to create a drainage density map. i.e., a drainage map is superimposed on a watershed map to determine the ratio of the total length of streams in the watershed to the total area of the watershed, which is then classified. D = L / A is the drainage density of the watershed, where D is the drainage density of the watershed, L is the entire length of the drainage channel in the watershed (km), and A is the total area of the watershed (km2). A watershed with appropriate drainage discharge should have a drainage density of less than 5, whereas moderate and poor watersheds should have drainage density classes of 1–5. Streams of second-ordered were found in the study area. Higher weights were assigned to locations with poor drainage density while lower weights were assigned to places with adequate drainage in the study area. Two major rivers in the research area were derived from the flow accumulation: The Ikpoba and Ogba Rivers (Figure 4.5). Using the conventional classification Schemes (1–5), the drainage density layer was further subdivided into five sub-groups. As shown in Figure 4.6, areas with extremely low drainage density were given a value of 5 and those with very high drainage density were given a value of 1.

v Criteria for Land Use and Coverage

One of the key issues in flood hazard mapping is land use and land-cover management because this is one component that reflects the current use of the land, its pattern and kind of usage, and the value of its use in terms of soil stability and infiltration. The ability of the soil to operate as a water store is influenced by land cover such as vegetation cover of soils, whether permanent grassland or cover of other crops. Rainwater runoff is significantly more common on bare fields than it is on fields with a thick crop cover. The passage of water from the sky to the soil is slowed by heavy plant cover, which lowers runoff. On the other hand, imperfect surfaces, such as concrete, absorb nearly no water. Land use, such as houses, highways, and slum areas, reduces the soil's penetration capacity and increases water runoff. In other words, land-use types act as water-resistant coverings, reducing the time it takes for water to accumulate; and, in most cases, they raise the peak release of water, enhancing fastidious floods. As a result, land use and land cover are critical factors in determining the likelihood of flooding. The research area's land use and land cover classes were created using municipal zoning maps. The study area's zoning-based land-use map was redistributed by dividing land-use types into six main classes and converting them to a raster layer. The area's existing land-use classes were grouped into five groups based on their ability to raise or decrease flooding rates. Figure 4.7 depicts the findings of the land-use/land-cover data study.

CHAPTER FIVE

5.0 Conclusions

In-depth data on field conditions, hydrologic statistics, and flood-defence structure components are required for comprehensive flood vulnerability and risk analysis for probability-based analysis and findings to accurately reflect the scope and severity of flood impact on particular locations. Reducing natural disasters, especially floods, is very challenging. The detection of flood susceptibility by remote sensing and GIS may be taken into account in regional planning and policy-making. to perhaps lessen the disaster's effects in the future.

This study's findings can be summarized as follows:

A GIS and remote sensing-based map was made that included specific criteria such as land cover, rainfall, drainage density, elevation, slope, and soil type to analyze the flood susceptibility area in the study area;

The majority of the study area – roughly 10 per cent, or 82.096sqkm. - is a High Flood vulnerable area. 75 per cent of the study area is Moderately vulnerable and 15 per cent of the study area has a low vulnerability.

Most of the Study areas such as Asaboro, Ekosa, Igbobaye, Ikpe, Ikpwei, Imasabor, Iyanomo, Obaretin, Obayantor, Obamahan, Ogbe-Orogho, Okuku, Ologbo, and Uhie villages are highly sensitive flood-prone locations in the study area.

The Avbiaman, Egun, Evbiakagba, Evbuomoma, Idogbo, Idumohen, Idunmwunivdiode, Niro, Obagie, Obazagbon, Obe, Obenevbueribo, Ogua, Oha, Ohen, Ohoghobi, Oka, Okavbor, Okavborhan, Okha, Okonaovi, Okuku, Oregbeni, Taboga, Uduehen, Uhkirhi, Uroho, Utesi, Utezi, and Uwosan village in the study area are Moderately vulnerable to flooding.

Villages such as Aduwawa, Echuwa, Egbal, Etete, Eyaen, Iguenan, Ironegbo Ogbesan, Okabere, Okavbogu, Otete, Urora, and Ute are low flood vulnerable zones.

The three main causes of flooding in the study area are land cover change, severe rainfall, and a high drainage density of 0.123m/m^2. Land subsidence is another factor that increases future flood risk.

5.1 Recommendation

There are many ways to lessen flood susceptibility. For this study raising the building's current lowest floor, including any associated appliances, above the Base Flood Elevation. Having a freeboard of one foot plus elevation for the drains is the most straightforward method of preventing flooding. Regrade the affected areas to ensure quick and effective runoff drainage (landscaping). The drains should be desisted regularly and should be channelled properly to the river.

While it is recommended to shift all buildings to a higher location away from a flood zone in places with a very risk. Moving the house to a higher location on the same piece of property might be possible if there is adequate area for it. Flood Dry securing the area to prevent floods To render the structure waterproof, the walls must be coated with waterproof coatings, impermeable membranes, or extra layers of masonry or concrete. In sewer lines and drains, back-flow prevention devices may be installed, and all openings below flood levels need the installation of shields. Buildings that cannot be relocated will be torn down and properly rebuilt elsewhere on the same site or transferred to a residence on another parcel of land that is not inside the authorized floodplains

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