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Flood Mapping of Federal Polytechnic Ekowe, Bayelsa State, Using Remote Sensing and GIS Tools

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ABSTRACT

The Federal Polytechnic Ekowe is one of the fast-growing polytechnics within the region, the main campus has been exposed to frequent flood hazards which were responsible for many damages in several areas of the main campus. This study was focused on the development of flood hazard map showing high vulnerability areas, medium/moderate vulnerability areas and low vulnerability areas of the main campus. The primary software used for the analysis and mapping was Esri's ArcGIS 10.8.1, Elevation dataset (Height), Landsat 9 satellite imagery, rainfall data, and digital soil map of the world. The present work introduced a flood hazard assessment methodology, using multi-criteria analysis and classification in the GIS environment. The results for the study showed that built-up area (94.42%) and vegetation (4.33%). The Elevation model showed minimum and maximum heights were 20.474m and 22.702m respectively. The Slope model also showed minimum and maximum slope percentage (s) were 0.00527 and 8.719 respectively. Other results obtained from multi-criteria were 28.61% for elevation and drainage distance, slope (12.71%) and precipitation (9.84%). In conclusion, more drainage infrastructure is required for the mitigation of flood water in the identified critical areas.

Keywords: Flood mapping, multi-criteria, remote sensing and GIS

1.0 Introduction

Floods are the most common and devastating natural hazard in the world (Berz et al., 2001; Sanyal & Lu, 2004). It is estimated that more than one-third of the world's land area is susceptible to flooding, affecting approximately 82% of the world's population. About 196 million people in more than 90 countries are exposed to catastrophic flooding (Karki et al., 2011). The frequent and severe incidents of flood events around the world have been attributed to climate change and sea level rise (Clark, 1998). Consequently, it is understood that risk associated with flooding will not subside in the future, where frequency and intensity of flooding is likely to increase and will undermine numerous areas across the globe (McCarthy, 2001; Jonkman, 2005). Disaster experts classify floods according to their likelihood of occurring in each period. A hundred-year flood, for example, is an extremely large, destructive event that would theoretically be expected to happen only once every century. This classification means that, there is a one-percent chance that such a flood could happen in any given year. Over the decades, possibly due to global climate change, hundred-year floods have been occurring worldwide with frightening regularity (Fairus et al., 2017). This is largely because of poor infrastructure and housing facilities, inadequate warning systems, low income, and preparedness (Wisner et al., 2004).

In Nigeria, Flooding has remained a prevalent environmental problem with negative implications on the survival of livelihoods as well as social and economic activities (Ifiok et al., 2022). The negative aftermath of flooding in Nigeria is often severe and is now of great concern to people and a challenging issue for governments (Emuh, 2008; Egbinola et al., 2014). According to the available studies, flooding in Nigeria is caused by weak implementation of the planning policies, streams, and channel obstruction due to indiscriminate waste disposal habits and human activities in floodplains (Ifiok et al., 2022; Ekpoh, 2015; Evans et al., 2017). The present trend and future scenarios of flooding demand accurate temporal and spatial information on their potential risks and hazards, particularly in developing countries like Nigeria.

The advancements in the fields of Geographical information science (GIS) and remote sensing (RS) over the last two decades have largely facilitated the operation of flood risk assessment and mapping. RS and GIS now play a major role in the management of natural hazards, such as flooding, as their occurrence and impact is spatially inherent (Coppock, 1995). First order flood risk management typically involves the generation of flood hazard maps showing areas prone to flooding based on historical flood data. However, in developing nations, historical data that accurately identifies flood extents and frequency can be poorly recorded and subjective, leading to inaccuracies in flood risk zoning and compromising mitigation efforts. Spatial technologies and infrastructure can play an important role in helping to acquire reliable, accurate and repeatably obtained spatial information on flood events. Moreover, spatial technology like GIS not only provides a way of visualizing the spatial distribution of flood events, but also allows the potential to further analyze and estimate likely damages caused by flooding (Clark, 1998; Haussmann et al., 1998).

Joyce et al., (2009) suggested that RS is an essential tool in every stage of managing disasters, giving quick-response teams valuable near real-time information used in assessment and recovery efforts. Joyce et al., (2009) also noted some challenges that needed to be overcome in connecting and obtaining information quickly. RS has proved to be a principal tool in the assessment, mapping, and management of natural disasters. Moreover, the integration of both GIS and RS typically extends on the potential limitations of a single technology, that when combined enables greater capacity to obtain timely spatial information and improved capacity for flood risk assessment, identification, and monitoring flood disaster (Pradhan et al., 2009). Combined methods of GIS and RS methods also helped to understand the causes of flooding by providing objective information on the spatio-temporal dynamics and evolution of flooding in specific areas (Brackenridge et al., 2003; Brackenridge et al., 2007). Importantly, Hyperspectral image sensors provide broad scale reliable and repeatable global coverage of moderate-to-large flood events over inaccessible areas or places where there are limited means of local flood surveillance information (Brackenridge 2006; Birkett et al., 2002).

The project area is usually flooded annually with over 90% of the main campus area covered with flood water, submerged Damp proof course (DPC) of building facilities such as hostels, guest house, workshops, classrooms, administrative offices etc) and bungalows which gets flooded at a considerable measure which damages properties within the main campus. This problem will be solved by the use of remote sensing and Geographical Information Systems (GIS).

2.0 Literature Review

Zakaria et al., (2017) worked on the development of flood map in Malaysia. The authors carried out this study to assist local citizens and governments to develop effective methods of reducing flood-related damage in the community over the long term. The material used were flood hazard maps produced from the Department of Irrigation and Drainage Malaysia (DID) using rainfall data and catchment characteristics, river alignment and cross sections data and floodplain data (topographic data) to obtain the flood hazard maps. The method involved the combination of the floodplain areas, flood depths and flow velocities generated from the 2D hydrodynamic models for several different return periods with a digital terrain model (DTM) using infraworks Remote sensing (RS) and Civil/structures (CS). Furthermore, Geographic Information System (GIS) software was used to model flood risk map and Digital Elevation Model (DEM). The results of the analysis produced Flood Hazard Map, Flood Risk Map and Flood Evacuation Map. In conclusion, the benefits of the integration of flood risk management into wider development management, urban planning and climate change adaption became very clear.

Argaz et al., (2019) worked on flood hazard mapping using remote sensing and GIS tools at souss watershed. The study aimed to identify and estimated the flood-hazard areas of the Souss river basin using multi-criteria analysis in a GIS environment. The materials used were rainfall data, Shutter Radar Terrain Model (SRTM) DEM of 1arcsec resolution (30m), global land cover data and land use and land cover map and geology map. Estimation of the flood hazard map areas and classification was performed by the assigned relative weights using ArcMap environment and thematic maps were produced. The linear combination of the thematic maps and the selection of the weights yielded the flood hazard map. In conclusion, the multi-criteria evaluation methods have proven to be a very helpful tool in aiding decision-making processes, seven input maps prepared (rainfall intensity, elevation, slope, land use, flow accumulation, geology and distance from drainage network and final model output maps like flood hazard and validation map was obtained.

Ifiok et al., (2022) reviewed the causes and effects of flooding in Nigeria. The study relied on previous academic/scholarly articles in achieving the aim. In this study, the author appraised flooding with specific reference to it causes and effects based on the existing studies. The materials used include temperature and rainfall data from NiMET. Flood water discharge quantity per year was computed from the temperature and rainfall data which represented the volume of flood water. Furthermore, the analysis was carried out using the multiple regression method. The outcome of the analysis showed that rainfall on roads without good drainage channel exact significant influence on flooding in urban areas. Conclusively, it was observed that the reason for increased number of flood vulnerable to areas include poor environmental planning/monitoring, housing development in flood prone areas, deforestation, haphazard developments resulting in the blockage of drains, poor waste disposal practices, negligence by government in designing and implementing policies at various levels as well as poor environmental planning and weak enforcement of policies contribute to flood occurrence.

Oladimeji et al., (2022) aimed at the assessment of flood risk and mapping of flood risk zones in Yenagoa, Bayelsa State. The materials involved in this study includes measuring tape, handheld GPS, google earth and Landsat imagery, SRTM data, ArcMap 10.0, Microsoft word and excel. The study used GIS and remote sensing technologies to generate and analyse data for the identification of different flood risk zones in Yenagoa. Spatial analysis adopted for this study included overlay analysis and geo-statistical analysis using ArcGIS, and to analyse the spatial variation, slope, land cover, flood levels and relief information for production of thematic maps (Digital Elevation Model (DEM), flood height map, land cover map). The thematic maps were overlaid to produce the flood risk map of Yenagoa. Research showed that the vast land area in Yenagoa is at high risk of flooding due to both natural and man-made factors.

Jonah et al., (2023) focused on the hydrology and hydraulic modelling using remote sensing and GIS and the development of digital database of the Ogbunabali floodplain, Port Harcourt, Rivers Sate, Nigeria. ESRI's ArcGIS 10.1, SURFER 10, SPOT image with 2.5m x 2.5m spatial resolution and the dataset was the topographic survey data obtained at 30m interval made up the materials used. Elevation data obtained using the total station were used to model contours, slopes, irregular triangular networks, flow directions, and flow accumulation, representing the hydraulic model of the floodplain. The geodatabase was digitized using the SPOT satellite imagery (2.5m x 2.5m spatial resolution). Conclusively, the study revealed that the dumpsite is gradually covering the available flow channel as that flood water will flow from steep slope (higher gradient) to gentle slope (lower gradient) area.

2.1 Theoretical Framework

2.1.1 Definition of Floods

There is a good number of definitions used to describe flooding as they mean something different to various researchers with respect to the context and location in which it is used (Brooks et al., 2005; Brooks, 2003).

Nicholls (2002), in defining floods, described it as a process whereby water brought into a drainage channel is more than it can convey. The abundant water flows over the banks and spreads out to the surrounding areas, creating the condition where we have a flood.

According to Burt et al., (2002), flood can be said to be an unusual water accumulation above the ground, which is created because of heavy rainfall, rapid runoff from concrete surfaces or high tides. Natural floodplains happen to be characteristics feature of some rivers. The most severe floods happen along coastal areas. In these regions, substantial precipitation and poor soil combine to bring about flooding.

Smith et al., (1998) demonstrated that there are several components utilised to depict the nature of flooding and its extent. For example, its range of coverage, the speed of flow, the volume of water released by time and duration. However, these factors are generally influenced by the amount of rainfall, soil type, the period of year, geomorphic characteristics as well as slope of terrain.

In general, the reasons for increasing flood events in many parts of the world are because of climate change, increasing population, changes in land-use pattern and land subsidence (Smith et al., 1998; Bhuiyan et al., 2012; Karamouz et al., 2011). Issues linked to flooding and populace vulnerability have considerably increased in last few decades because of a few factors including urbanization in the areas liable to flood, increase in the density of the households, sub-standard constructions and settlement pattern and changes in the land-use pattern (Pelling 2003). In addition, the dangers of floodwaters are associated with various factors such as rate of rising waters and recurrence, load of sediment, water depth, velocity, and duration (Klijn, 2009).

2.1.2 The Principal Types of Floods

Various nomenclatures assigned to describe types of flood events which characterize floods according to the source of water, the geography of the area receiving it, the river course and velocity, or the cause. Major flood types include fluvial floods, urban floods, coastal floods, and pluvial floods. Coastal floods are brought about by extreme storm events bringing severe onshore coastal winds and vast waves typically coupled with high tides that floods estuaries and coastal zones with ocean water (Klijn, 2009; Wright et al., 2008). Usually, large areas are affected and means of living and human lives can be lost in the process. Forecasts of a coastal storm can normally be between a couple of hours to days ahead (Klijn, 2009) while the conceivable rise in the level of the sea can happen between four to eight hours after the storm surge has begun (Wright et al., 2008). Flooding along the coast is usually followed by huge, battering waves and floating debris that lead to erosion of the beach and large-scale destruction to infrastructure along the coastline (Wright et al., 2008). River floods, on the other hand, are caused because of long periods of precipitation in the catchment zone that led to an increasing level of water that eventually overflows the banks of the river (Wright et al., 2008). This type of flood starts slowly and is typically confined to floodplains (Wright et al., 2008; Wisner et al., 2004). They are often known by their slow speed that effect largely inundated zones that can bring about many damages but few fatalities (Klijn, 2009). Flash floods occur in hilly areas, in the upper level of the basin of a river during extreme rainfall (Wright et al., 2008; Klijn, 2009). Even though this type of flood occurs under the subdivision of river flooding (Wisner et al., 2004; Wright et al., 2008), they are regularly considered as another type of flood because of the extreme damage and high fatalities they can bring about. Klijn (2009) refers to this type of flood as “small-scale killers” as these floods are the small types that can happen regularly. The high speed and load of debris of this type of flood (Wright et al, 2008) and the trouble in anticipating them (Klijn, 2009) make early warning and evacuation a big problem. The Ponding or Pluvial flood types occur when water from precipitation begins to accumulate in low-lying areas with soil types that are clayey in nature (Klijn, 2009). This type of flood starts slowly and can be predicted days ahead, though they can bring about major damage, particularly in urban zones, however not often with fatalities (Klijn, 2009). Lastly, urban flood types can result from flash floods, river floods or coastal flooding. Urban flooding often results from a lack of good drainage, impervious surfaces, coupled with high rainfall. Most urban areas have paved surfaces with little soil and poor drainage systems, which do not allow the amount of rain that is falling to drain away. In developing countries, where there is little or no drainage/storm water systems, water disperses quickly over impervious surfaces and is deposited in another place leading to a flood. The condition is known for its repetitive and systemic effect it has on the area, regardless of whether they are close to or located in a floodplain or water body (Klijn, 2009).

2.1.3 Causes of Flood

Floods usually are most caused by excessively prolonged and/or heavy rainfall when the natural watercourse does not have the ability to convey surplus water. However, there are also other ways in which floods can occur apart from heavy or prolonged rainfall, which can be ascribed to other natural hazards or human-caused hazards like dam failure or storm surge associated with a tropical cyclone or high tides coinciding with higher than ordinary river levels (Wisner et al., 2004). Ojo (2011) identified that floods in developing countries are often caused by economic pressures from developers, lack of institutional capacity at the municipal level, poor or lack of standard drainage system on roads, unrealistic regulations, unregulated developments, and the ineffectiveness of planning regulation by permitting development on flood plains. Climate change is a significant driver of flooding, and it is a problem that is identified with the physical, social, economic, and cultural environment of any country. This is a key component of the environment that mould and re-mould different individual activities in a particular environment. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change “as a change of climate which is attributable directly or indirectly to human activity that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods" (UN-ISDR, 2009). Human activities such as burning of fossil fuels, industrialization, and deforestation, and technology development, natural factors such as solar radiation, agricultural activities and urbanization are significant causes of climate change (Mshelia, 2005). This change in the climate is making weather less predictable, particularly in the developing countries such as Nigeria where means and equipment to manage and predict weather conditions are not sufficient (Nwafor, 2007). This unpredictability of precipitation during the rainy season has brought about untold hardship in many regions across the country.

2.1.4 Hazard Associated with Flood

Notably, flood events do not necessarily constitute a hazard where it is a necessary requirement of some natural ecosystems and where regular "controlled" flood events necessitate irrigation for crops. However, flooding can become a hazard when it is uncontrolled and where there is the potential for negative impacts on infrastructure and human lives. This is more evident in coastal and floodplain areas where the desire to live in areas susceptible to flooding out ways the perceived risk. Flood effects can be grouped into primary, secondary and tertiary or long-term effects (Klijn, 2009). Primary flood effects are those that happen because of direct contact with flooded water, such as injuries and loss of life, secondary flood effects are those associated with health implications and disruption of services. Tertiary flood effects are those long-term effects such as economic loss due to disruption to food production and tourism or restoration of ecosystems and infrastructure due to realignment of river channels. All through the last century, flood events have been one of the costliest disasters in terms of both human casualties and property damage. Pelling et al., (2004) estimated that over one hundred and ninety-six million individuals in more than ninety nations are vulnerable to flooding calamity each year. Floods have effects on both individuals and communities and have environmental, economic, and social consequences. The impacts of floods can also be both positive and negative, and they vary greatly depending on the flood extent and the location of the flood, and the vulnerability and value of the built and natural environments they affect. However, the negative effect of flooding is usually more than the positive. As indicated earlier, a rise in the occurrence of flooding and its effects can be attributed to the impact of climate change and the propensity of people to dwell in areas that are liable to flood (Klijn 2009; Wisner et al., 2004). Despite the risk, people living in areas prone to flooding often do so as a matter of ignorance or by choice. However, many people living in flood affected areas or move back into areas where severe flooding has occurred, do so as they have little choice. This is particularly true in developing countries where flood plains are often crucial to their means of living. They move back to these areas (Wright et al., 2008; Wisner et al., 2004) where the soils are rich in nutrients and where the river provides water for aquaculture and irrigation of crops like the Sokoto plains where agriculture is their main practice and source of income. Archived and reported severe flood events/disasters in Nigeria afford good insights into flood related issues and the potential extent of flood risk in the country. For example, during the 2012 flood event, 33 out of the 36 states in the country was affected and an estimation of about 7million individuals were affected by the floods, leading to about 363 deaths and more than 600,000 houses damaged or destroyed leading to the internal displacement of 2,157,419 people (Egbinola et al., 2014). This is the worst the country experienced for more than 40 years. The 2012 flood lasted seven days and during this time, Sokoto State experienced a complete flood season due to the collapse of the dam on the Rima River, leaving 50 villages devastated by floods, killing more than 130,000 people in 9 districts area must be relocated and the deaths of eight people. Out of the 50 villages in this location, 20 were completely submerged, while major roads and bridges were destroyed.

2.1.5 Disaster Risk and Flood Management

It is important to understand common concepts utilized in disaster risk management because this study forms a component of a progression towards minimizing risk. Different terms and definitions are additionally included for a more comprehensive overview. Disaster Risk Reduction (DRR) underpins the motivation for this study, and this defined as the structured growth and application of strategies, practices, and policies to reduce vulnerabilities and disaster risks in every part of a community, to avoid or to reduce the harmful effects of hazards (UNISDR, 2004). As earlier, pointed out in the first chapter, natural disasters, and floods specifically have become recurrent and this is likely to continue in the future because of climate change. It might, hence, not be attainable to mitigate all floods and their associated risk. What is important though is to attempt to comprehensively understand flood risk and related impacts in the context of DRR. This is made possible by obtaining baseline information through the development of flood risk, inundation, and hazard maps, which can be utilized to outline proper measures to control and reduce the impacts of flooding and to strengthen and shape the ability by which people can adapt. Notably, flood risk/vulnerability maps are those maps showing the projected damage or losses experienced by flooding, whereas flood hazard maps are those showing the inundation area.

2.1.6 Hydrological Modelling

In situations where water scarcity, surplus, or dissolved or solid content are the main concerns, hydrologic modeling aims to provide answers to environmental transport challenges . There is no one ideal model due to the nature of environmental forecasts. Instead, a variety of tenable options exist, contingent upon the objective and required intricacy. Hydrologic modeling has historically relied too heavily on mathematics at the expense of real knowledge for this and other reasons, necessitating a more thorough assessment of suitability (Klemeš, 1997).

Model selection usually depends more on familiarity than suitability (Addor et al., 2019). According to Troch et al. (2009), process uncertainties, the strong influence of heterogeneities, and other poorly understood and poorly characterized natural phenomena provide significant challenges to the profession of hydrologic modeling. As a result, there are many distinct hydrologic models that are unreliable and falsifiable in all but the most basic circumstances.

Global phenomena act locally in response to local conditions, while the hydrologic cycle is a worldwide phenomenon that causes local reactions to recurrent large-scale meteorological stimuli. This leads to the phenomenon known as the uniqueness of site in hydrology (Beven, 2002). In terms of process sensitivity, hydrologic responses frequently display threshold behaviors as a function of system state, both in space and time. This results in states-space regions where some processes and associated parameters are irrelevant. The presence of heterogeneity and the highly non-linear and indeterminate nature of material constitutive interactions pose challenges to precise mathematical formulations that do not require great spatial resolution. Hydrologic state variables are often intermittent and discontinuous, which makes it difficult to describe them mathematically using continuum methods.

Environmental forecast problems belong to the category of "wicked problems" for a variety of reasons, but most often because "it depends" is the response to any hydrologic query. Simplified modeling approaches with highly uncertain prediction confidence bounds are often seen as better than complicated approaches with highly uncertain inputs and process descriptions, with the exception of particularly data rich situations (Hrachowitz et al., 2014). The history of computational hydrologic modelling spans from pre-computer age conceptual models through the present-day continental-scale models running on massively parallel supercomputers. The contemporary state of the art in hydrologic modelling is described below, with emphasis on broad classes of approaches, applicability, and limitations on predictability. So, one might ask the question: Why model at all? Flowing water has shaped the surface of Earth. As a liquid or a solid, the motion of water across the land surface causes erosion and sedimentation, lowers the height of mountains, and adds new land in river deltas. Through the process of weathering, water's chemical reaction with rock creates soil. All life on Earth is impacted by the dissolved elements, nutrients, pollutants, and silt that liquid water transports. A hydrologic model is usually used to obtain insight and understanding by those who are interested in forecasting the impacts of water mobility, especially liquid water, on or beneath the surface of the earth (Fortin et al., 2001). A hydrologic model essentially replicates the flow, flux, or variation in water storage over time in one or more natural hydrologic cycle components.

2.1.7 Impact of Hydrological Modelling in Flood Mapping

A hydrological model plays a crucial role in the production of flood hazard maps in the following ways.

Prediction of flood behaviour: Hydrological models help in predicting how water will behave in a river basin during intense rainfall events. This includes the estimation of water flow, water level fluctuations, and potential flood areas (Hrachowitz et al., 2014). Identifying flood-prone areas: By using hydrological models, areas that are prone to flooding can be identified. This is essential for creating accurate flood hazard maps and for effective land-use planning and development control in these areas (Burrough, 1986). Risk assessment and management: Hydrological models provide valuable information for assessing flood risk, which is essential for effective flood risk management and emergency preparedness (Bronstert, 2003).

Infrastructure planning: Flood hazard maps produced using hydrological models can be used to inform the planning and design of infrastructure such as dams, levees, and drainage systems to mitigate flood risks (Flood Map for planning, n.d.). Policy and decision-making: Hydrological models provide scientific data that can be used to inform policies and decision-making related to flood management, disaster response, and environmental conservation (ISDR, 2004).

3.0 Material and Method

3.1 Study Area

The study area is the permanent site main campus of the Federal Polytechnic Ekowe, a Federal Government Higher Education Institution established in 2009 in Southern Ijaw Local Government Council, Bayelsa State, of Nigeria. It is located at Latitude 4° 42’51”, Longitude 6° 5’18” and Latitude 004° 42’27”, Longitude 006° 05’44.6”. The campus is situated in Ekowe Town, Bayelsa State, Nigeria, along the banks of River Nun, one of the major tributaries of River Niger that flows into the Atlantic Ocean. The project site is surrounded by River Nun to the south-east and north-east, by Ekowe Town to the south-west, and by a thick mangrove swampy forest to the far west.

Access to the study area is primarily through the river Nun network, as the site is connected only by waterways to the State capital (Yenagoa) and other nearby communities. The site can be accessed through a waterway of about 22-km via Angiama Community jetty and 28-km from Berger Roundabout at Yenegoa, the State capital. The common modes of transportation between Ekowe and Angiama are by canoe or flying boat, while from Angiama to Yenegoa, transportation options include foot, bicycle, motorcycle, and motor-vehicle.

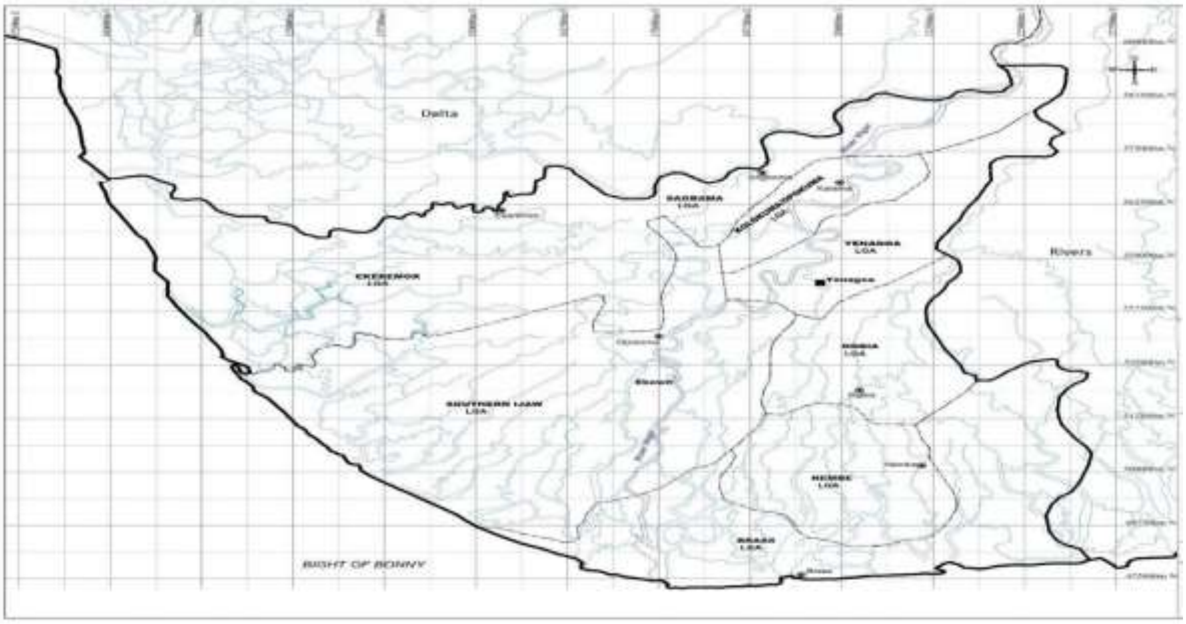


Figure 1.2: Map of Bayelsa State.

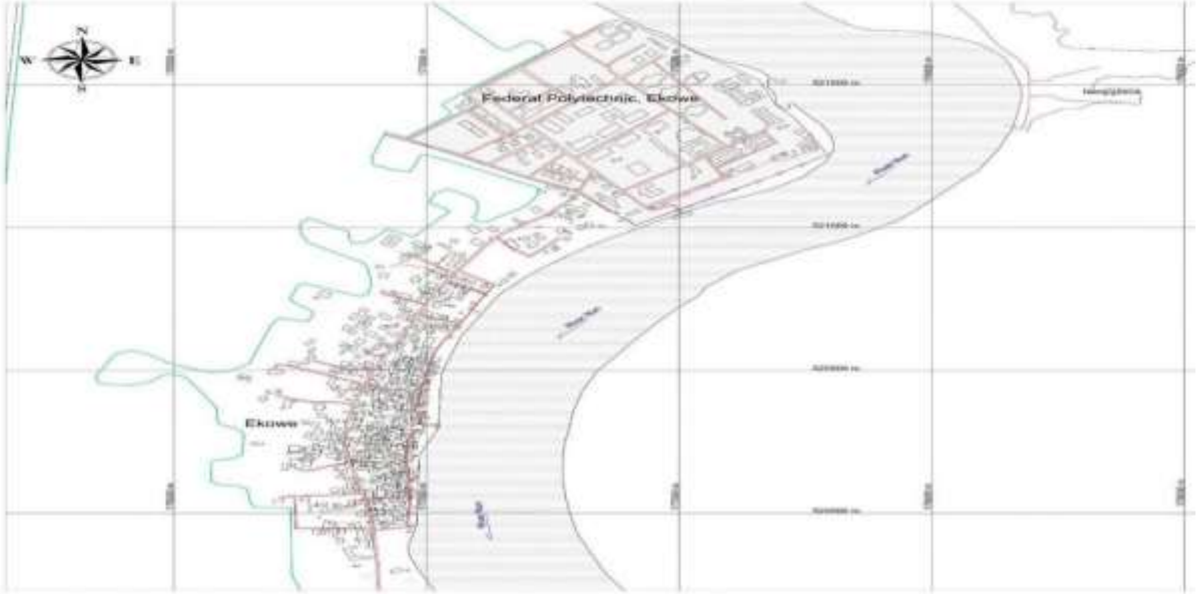


Figure 1.3: Map showing the Federal Polytechnic, Ekowe

3.1.2 Relief and Drainage

The study area is in the Niger Delta region of Nigeria, which experiences a tropical climate with distinct dry and wet seasons. The area is renowned for its plentiful water resources, with numerous rivers, streams, and creeks running through it. The main river in the area is the river Nun, which is a significant tributary of the river Niger. Other important rivers in the area include the Sagbama Creek, the Ekole Creek, and the Osanama Creek (Berezi et al., 2019). The river channels and creeks in the area are generally shallow, with depths ranging from 1 to 5 metres. During the rainy season, these channels and creeks experience a significant increase in flow rate, and they can quickly overflow their banks, leading to flooding of the surrounding areas.

According to hydrological information gathered from members of the communities, the study area experiences a rainy season that typically lasts from April to October. The heaviest rainfall typically occurs in July and August when continual rainfall, lasting up to seven (7) days, could be experienced. This is particularly concerning given the gently sloping topography of the area, which makes it prone to large overland runoff flow flooding during periods of heavy rainfall.

Flooding is most likely to occur between September and October when the groundwater level has become saturated, resulting in peak flood. The heaviest flooding typically occurs in October, with a high likelihood of large overland runoff flow flooding. It is important to note that flooding in the area is not limited solely to the project site, but it also affects the surrounding communities (Berezi et al., 2019).

3.1.3 Climate and Vegetation

Rainfall

The project area, as reflected through Bayelsa State, has a tropical climate which is influenced by the movement of the Inter-Tropical Discontinuity, comprising of two wind systems. These are the moisture laden Southwest Monsoon from the Atlantic Ocean, and the dry cold Northeast Trade Winds from the Sahara Desert. The former more than the latter most significantly, determine the climatic conditions with the influence of the monsoon wind gradually weakened Northwards. The project area is classified under rainfall zone 1 under the Nigeria rainfall distribution map with annual precipitation of 2270mm for rainfall gauge station at Port-Harcourt or data captured as at 1995-2005. Generally, only few months are without an appreciable amount of rainfall, with its duration and intensity being high throughout the year. Two periods of heavy rainfall can be recognized. The first is from March to July while the second is from August to November. In between these periods of peak rainfall is the distinctive break is in between December and February. Thus, the rainfall pattern is characterized by the double maximum regime associated with equatorial climates. The difference in precipitation between the driest month and the wettest month is 312 mm. The month with the highest relative humidity is October (88.61 %). The month with the lowest relative humidity is January (73.82 %). The month with the highest number of rainy days is October (28.67 days). The month with the lowest number of rainy days is January (14.23 days). The dry season is between December and February while the wet season is mostly between March and November. The mean minimum temperature observed is 27.4°C and the mean annual rainfall 2909mm (Amukalli et al., 2018).

3.1.4 Geology and Soil

The study area is situated in the Niger Delta region of Nigeria, which is known for its complex geology and diverse soil types. The geology of the area consists of alternating layers of sedimentary rocks, including sandstone, shale, and clay, that were deposited over millions of years by the Niger and Benue rivers (Berezi et al., 2017). The underlying geology is primarily composed of sandstones and shales of the Agbada Formation, which are overlain by the younger coastal plain sands and clays of the Benin Formation. The soils in the area are highly varied and range from sandy loam to clayey soils. The soils are primarily derived from the underlying geology, with the sandy soils derived from the coastal plain sands, and the clayey soils derived from the shales and clay stones of the Agbada Formation. The soils are generally poorly drained, which contributes to the high groundwater levels in the area. The hydrogeology of the area is complex and highly influenced by the geology and soil types (Berezi et al., 2017). The area is underlain by a thick aquifer system composed primarily of sandstones and interbedded shales. The aquifer system is highly permeable and provides a reliable source of groundwater for both domestic and agricultural purposes. However, the shallow nature of the aquifer system makes it highly susceptible to contamination from human activities such as farming, oil and gas exploration, and waste disposal.

3.2 Data Acquisition

The datasets used for this study includes elevation data, Landsat 9 (OLI & TIRS) satellite imagery with spatial resolution 30m, digital soil map of the world (DSMW), and CRU precipitation data of the world for a 10-year period (2011 – 2020) from USGS.

3.3. Hard and Software used

Hardware used were:

1. Laptop (HP pavillion11th Gen Intel(R) Core (TM) i5,11.8 GB usable, 64-bit operating system, x64-based processor).
2. HP Office jet Pro 7720 Wide format, and the software contained

1. ESRI's ArcMap 10.8.1.
2. Microsoft Excel 2016.
3. Microsoft Word 2016.

3.4 Classification

Supervised classification was carried out in ArcGIS using the trained data set to estimate the land use and land cover of the area. The bands combination for the study involved 7, 6 and 4 of Landsat 9 imagery of resolution of 30 metres.

3.5 Multi-criteria Evaluation

Multi-criteria evaluation was done in accordance with elevation data, Digital Soil data, precipitation data, land use and land cover data, and slope. These factors were assigned weights to different data set that defined flood degree. In order to estimate the flood-hazard areas, the study area was divided into five regions characterized by different degrees of flood hazard (very high, high, moderate, low and very low). This classification was performed by considering the factors that form and influence a flood and by assigning relative weights to them, this process was performed in a Geographic Information System (GIS) environment and thematic maps were produced for each parameter, the linear combination of the thematic maps and the selection of the weights yielded the final map of flood hazardous areas.

3.6 Distance from Drainage Network

Distance from drainage network was generated the stream shape file using the ArcMap tools the following respective order; Arc toolbox > spatial analyst tool > distance > Euclidean distance was double-clicked to open the dialog box where the study area stream shape file was inputted to produce the distance from drainage raster.

3.7 Elevation Data

The point data used for this study was sourced from an existing topographical survey of the study area executed April 2023. This survey was carried out using a Differential Global Positioning System (DGPS) to capture the spot heights and flood levels markings on buildings in the areas submerged in flood water.

3.8 Digital Elevation Model (DEM)

The DEM was produced using the points data obtain from the existing topographical survey, inputted in the MS excel with a .CSV file format. A folder was created for this MS excel and connected to the ArcMap environment through the ArcCatalog tool of ArcGIS software package. The MS excel file was imported into the ArcMap workspace, the CSV file was right clicked to select the "Display XY data" and the X field and Y field where specified to display the points as shape file. Spatial analyst tools were clicked in the Arc toolbox to double click on interpolation > kriging to process the point data into a surface data.

3.9 Slope

The slope model was generated by clicking the Arc toolbox > Spatial analyst tools > Surface and double-clicking slope where the DEM raster was inputted, output measurement selected was percent rise to produce the model.

3.10 Flow Accumulation

Flow accumulation was produced by opening the Arc toolbox, clicked spatial analyst tools > hydrology > flow direction, the D8 flow direction type was selected to produce the flow direction raster. This raster was then used to produce the flow accumulation of the study area.

3.11 Average Annual Precipitation

Average annual rainfall model was generated using the CRU precipitation data downloaded in NETCDF format from the CRU portal for a ten-year period (2011 -2020). Multidimensional tools was clicked, "Make NETCDF Raster Layer" was double clicked to have the dialog box that allows the input of the CRU NetCDF file and converts it to raster data. Spatial analyst tools were then clicked, local > cell statistics where the CRU raster data was inputted, overlay statistics set at SUM to produce the Summed precipitation raster, next tool clicked was map algebra > raster calculator with the summed precipitation raster divided by 10 (total precipitation period) to produce the average precipitation raster. Next Conversion tools clicked > from raster > raster to points, here the average precipitation data was inputted to produce points shape file of the average precipitation. The shape file of Nigeria's administration boundary was used to clip the average precipitation point shape file; spatial analyst tool was clicked then Interpolation > IDW double clicked to input the average precipitation point shape file to have the average precipitation raster data from which the study area was extracted using the "Extract by Mask" tool.

3.12 Soil Type

Soil map of the study area was generated using the Digital soil map of the world (DSMW). The file was added to the ArcMap environment as a polygon shape file. The polygon shape file was then geo-referenced to the WGS 84 geographic coordinate system and then projected to the UTM Zone 32N after the extraction of the study area. The soil shape file shown in the ArcMap table of content was right clicked, "Properties" selected > "Symbology" > "Value field" set to be "SNUM" > "Add all values" and click OK. Final Output was then produced by clicking the following tools: Arc Toolbox > Conversion tools > To Raster > Polygon to Raster, polygon shape file inputted in the dialog box to generate the soil map in raster format.

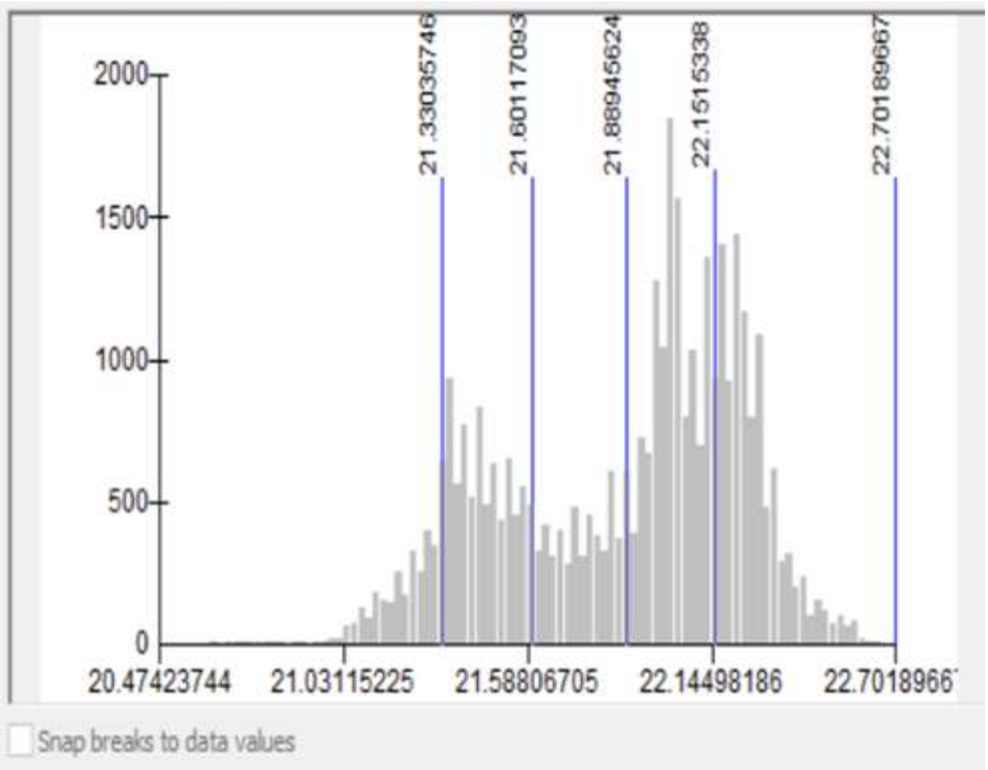
4.0 Results and Discussion

4.1 Elevation Map

The role of topography in flood brutality and for the determination of a flood-prone area is significant. Topographic factors have a direct effect on flow size and runoff velocity. Water flows from higher to lower elevations and flat areas of low elevation may flow quicker than higher elevation. Elevation model was classified using the natural break (Jenk) into five classes as shown in Figure 1. It's observed that high elevation was domicile more in the South-eastern area of the map. Statistics of the results of the elevation model was summarised in Table 1.

Table 1: Classification Statistics

Minimum	20.474m
Maximum	22.702m
Sum	830,722.324
Mean	21.880m
Standard deviation	0.36



☐ Snap breaks to data values

Figure 1: Histogram Showing the Natural Break Classes as used in the Raster Model

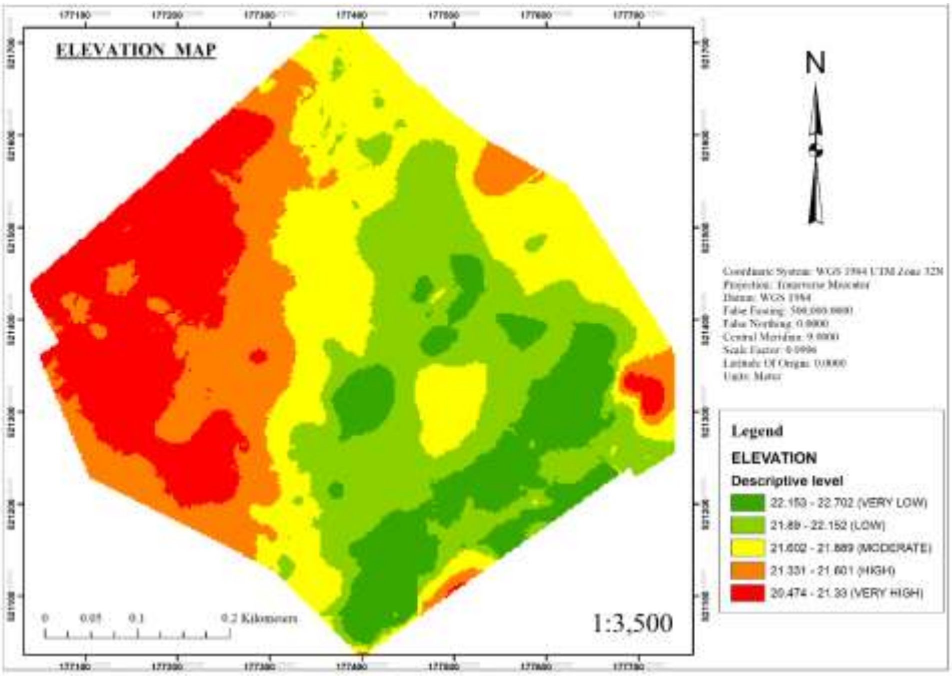


Figure 2: Elevation Map

4.2 Slope Map

The slope model depicts the maximum rate of change from a cell to its neighbours, which was typically used to indicate the steepness of terrain. Slope influences the amount of surface runoff and infiltration. Flat areas of low elevation may flood quicker than areas of higher elevation with a steeper slope. Slope model was classified using the natural break (Jenk) into five classes as shown in Figure 3. More than 90% of the study area was observed to have slope ranging from 0.00529% - 0.55203%, as the model's pixel count ranges from 1000 to 4000 (Figure 4). Statistics of the results of the slope model was summarised in Table 2.

Table 2: Classification Statistics

Minimum	0.00529%
Maximum	8.7193%
Sum	28,315.524
Mean	0.75832%
Standard deviation	0.7353

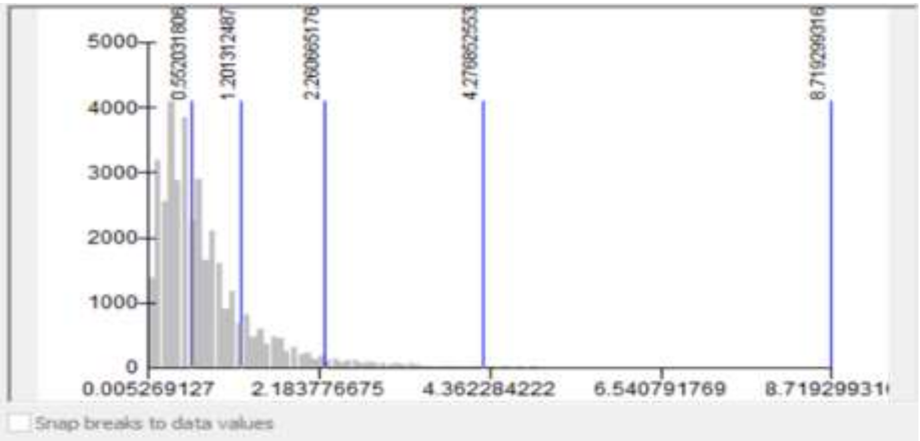


Figure 3: Histogram Showing the Natural Break Classes as used in the Raster Model

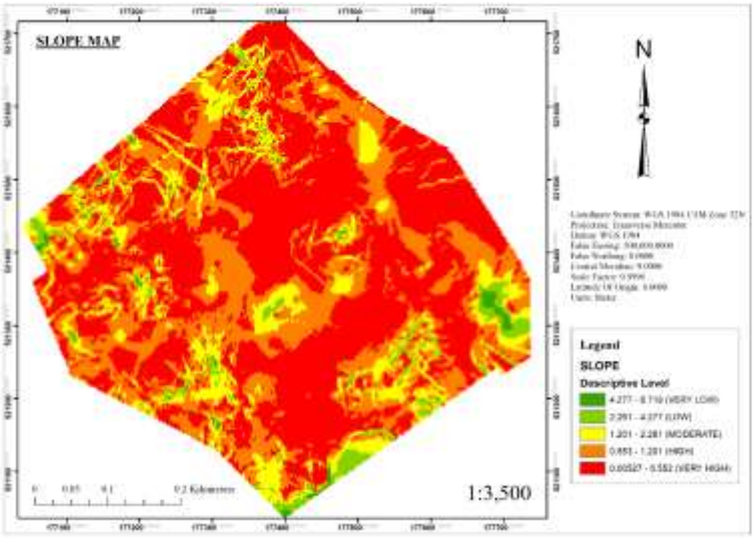


Figure 4 Slope Map

4.3 Flow Accumulation

The flow accumulation tool models accumulated flow as the accumulated weight of all cells flowing into each downslope cell. Flow accumulation model was classified using the natural break (Jenk) into five classes as shown in Figure 5. The downslope cells with higher cell values of accumulated flow showed the path through which the surface overflow/runoff is of higher concentration. Thereby, describing the behaviour of runoff within the study area and the Statistics of the results of the flow accumulation model was also summarised in Table 3.

Table 3: Classification Statistics

Minimum	0
Maximum	2221
Sum	519,815
Mean	13.6912
Standard deviation	69.382

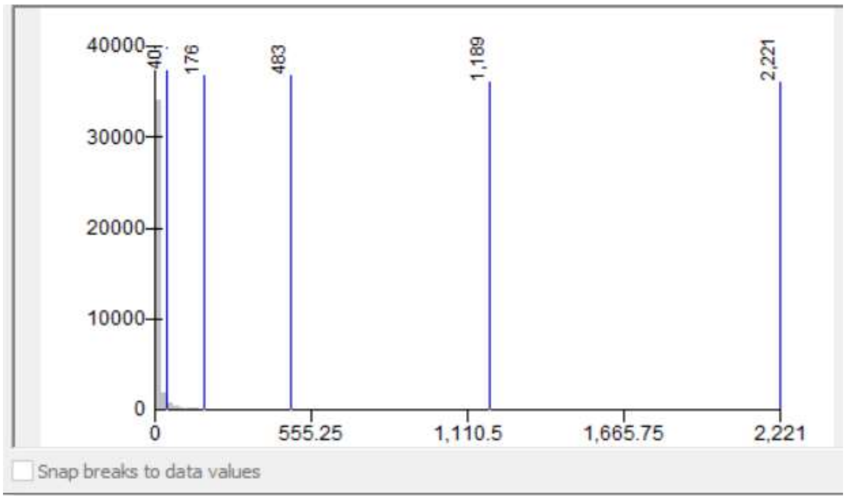


Figure 5: Histogram Showing the Natural Break Classes as used in the Raster Model

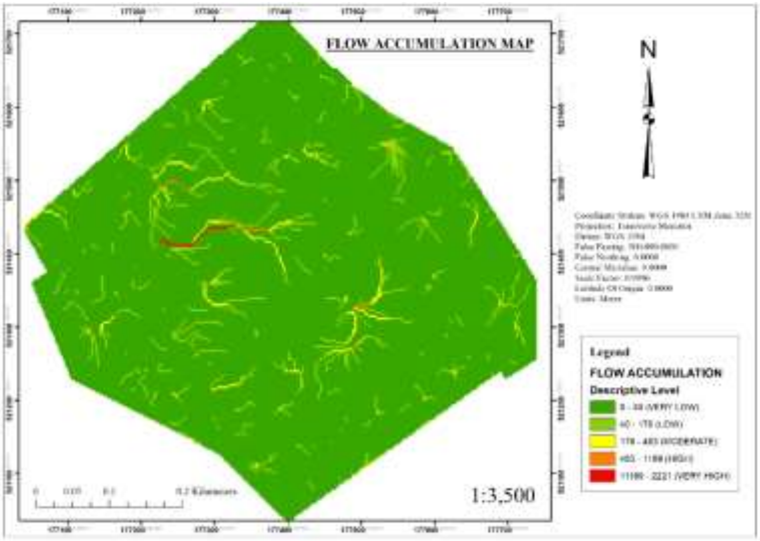


Figure 6: Flow Accumulation Model

4.4 Rainfall

The rainfall map expresses average rainfall intensity over a ten-year period. The gridded rainfall data was interpolated within the GIS environment using the inverse direct weighting (IDW) method. Rainfall map was classified using the natural break (Jenk) into five classes as shown in Figure 7. High rainfall averages were observed especially in the Southern and south-eastern part of the study area. Statistics of the results of the rainfall map further summarised in Table 4.

Table 4: Classification Statistics

Minimum	2254.133mm
Maximum	2255.313mm
Sum	726,012.197
Mean	2254.696mm
Standard deviation	0.3191

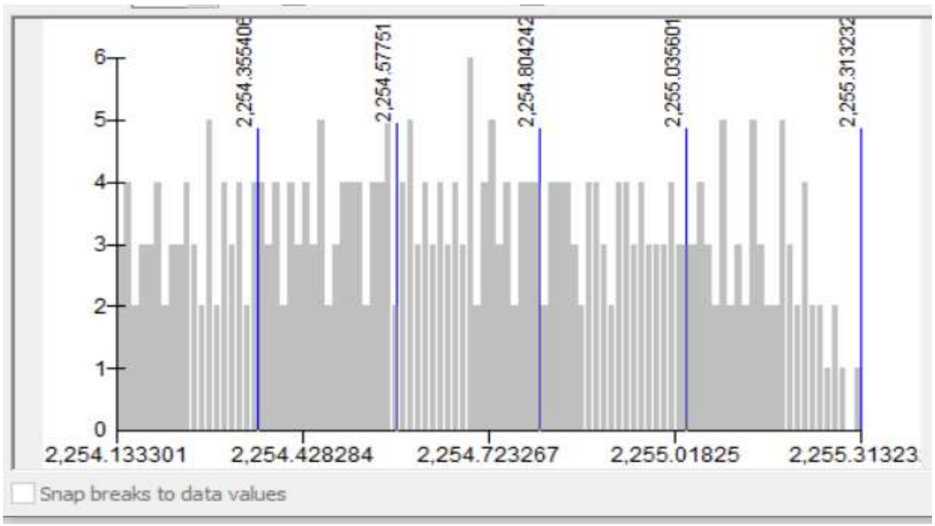


Figure 7: Histogram Showing the Natural Break Classes as used in the Raster Model

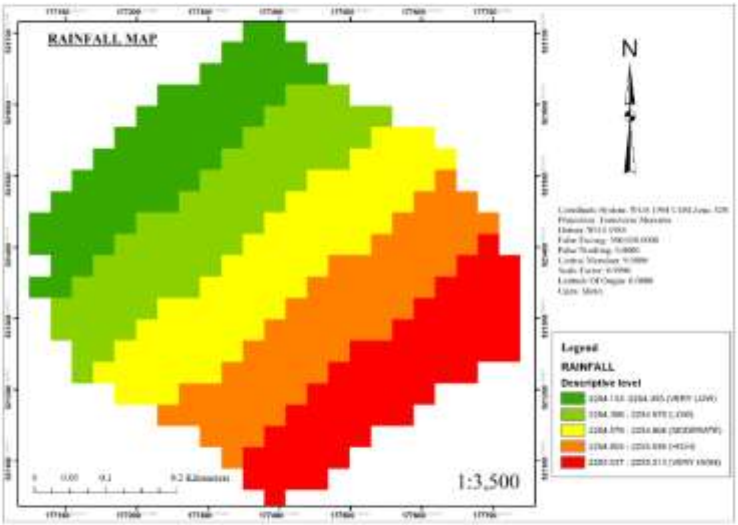


Figure 8: Rainfall Map

4.5 Soil Type Map

The soil type of flood hazard areas is an important condition because it may increase/extenuate the degree of flood events, permeable formations support water infiltration, through flow and groundwater flow. The soil type classified uniformly within the study area was identified as clayey loam as derived from the Food and Agriculture Organization (FAO) digital world soil database (Table 6). According to FAO, soil permeability relates to soil texture and structure, the size of the soil pores is of great importance with regards to the rate of infiltration and percolation. The average permeability for different soil texture was shown in Table 5. Hence, the soil texture was deemed categorized as semi-permeable.

Table 5: Soil Type	**Average Permeability (Cm / Hour)**
Sand	5.0
Sandy Loam	2.5
Loam	1.3
Clay Loam	0.8
Silty Clay	0.25
Clay	0.05

Table 6: Detail of soil type. Source: FAO Digital Soil Map of the World Database

Record Number	**Mapping Unit Name**	**% of MU with Coarse Texture**	**% of MU with Medium Texture**	**% of MU with Heavy Texture**	**% of Dominant Soil in the MU**	**% of MU with Flat Topography**	**% of MU with Rolling Topography**	**% of MU with Mountainous Topography**
1193	G2-2/3a	0	65	35	70	100	0	0

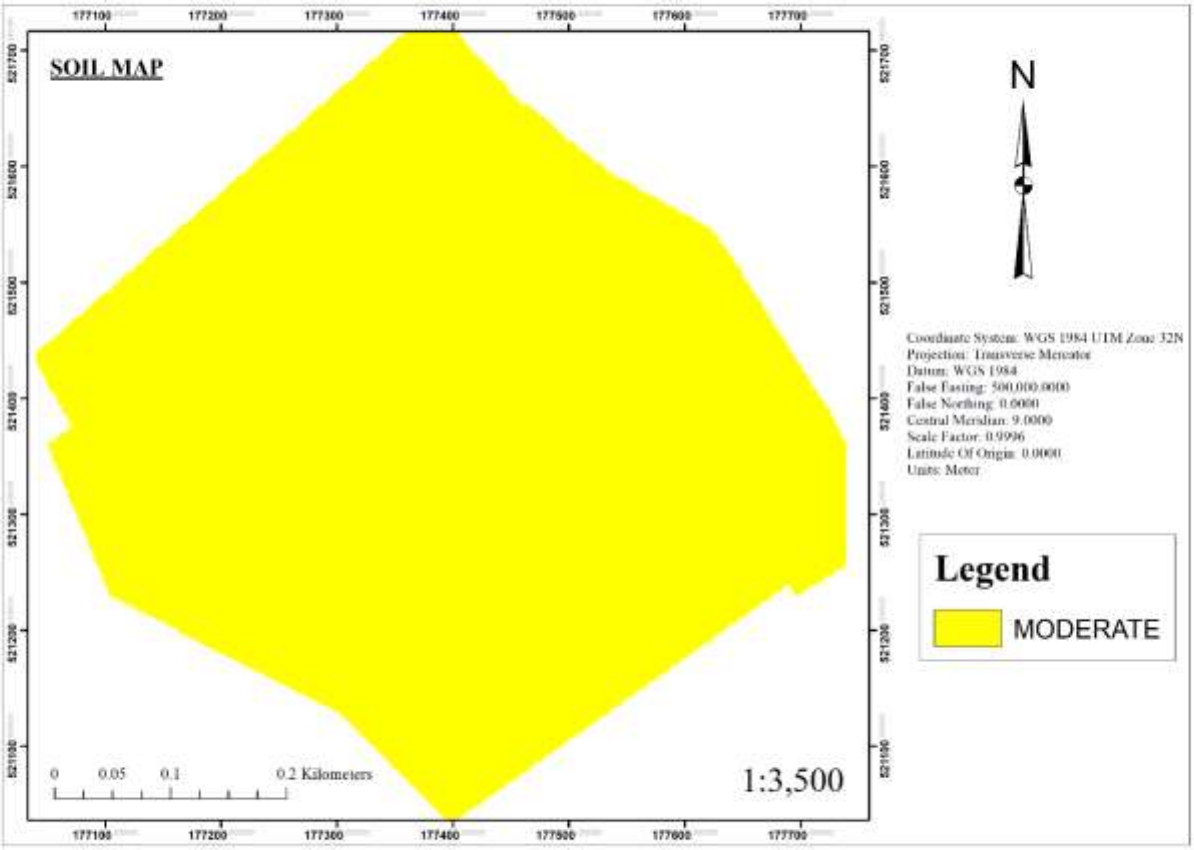


Figure 9: Soil Map

4.6 Land Use Map

Land use and nature of land cover are also key factors responsible for flood incidence, Land use is the surface cover of the earth in a specific location e.g., (vegetation type, an artificial structure). Land use influences infiltration rates, the interrelationship between surface and groundwater as well as debris flow, thus, while forest and lush vegetation favour infiltration, urban and pasture areas support the overland flow of water. The result for the study showed that 94.42% of the study area was classified as built-up containing buildings, paved surfaces such as roads, concrete interlocked landscaping etc while 4.33% of the study area was classified as vegetation content trees.

Table 7: Land Use Classification

FEATURE CLASSES	AREA (SQ. MTS)	PERCENTAGE (%)
Vegetation	12600	4.33
Built up	274500	94.42

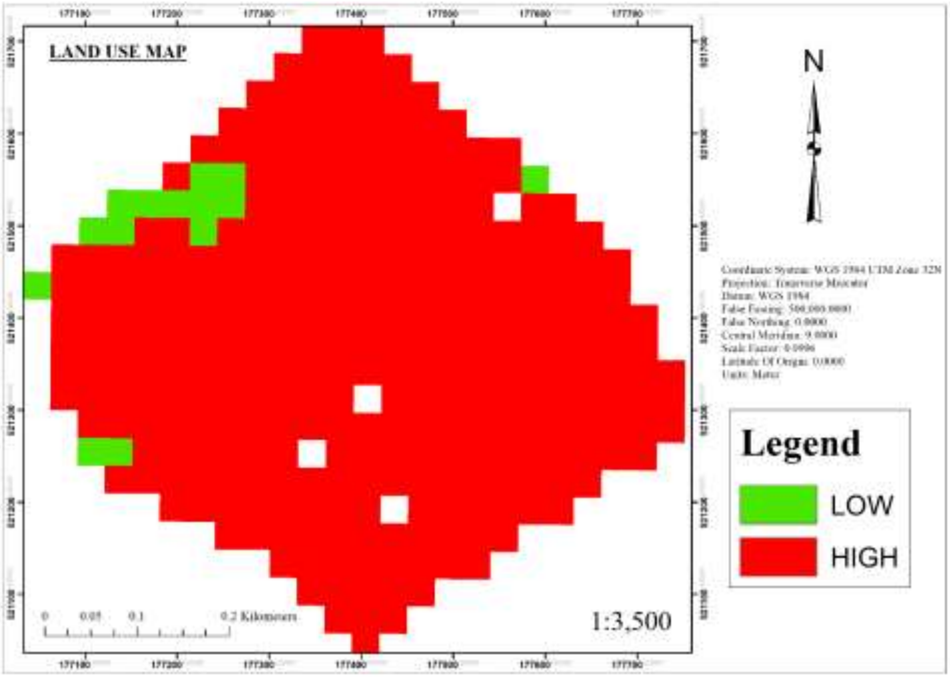


Figure 10: Land Use map

4.7 Distance from Drainage map

The distance from drainage map depicts the distance from each stream/flow/runoff path (i.e. downslope cells with the high number of cells flowing into them) in the raster to the closest source. Distance from drainage map was classified using the natural break (Jenk) into five classes as shown in Figure 10. The major flow paths were domicile within the central area of the study area with its distance to the source, at an average distance of 35.655m. The shortest distances from runoff path to the source was within the range of 0m – 24.037m and 24.038m – 47.273m, as highest cell counts within the study area. Statistics of the results of the distance from drainage map, summarised in Table 8.

Table 8: Classification Statistics

Minimum	0
Maximum	204.317m
Sum	3,253,576.61
Mean	43.9673m
Standard deviation	33.5579

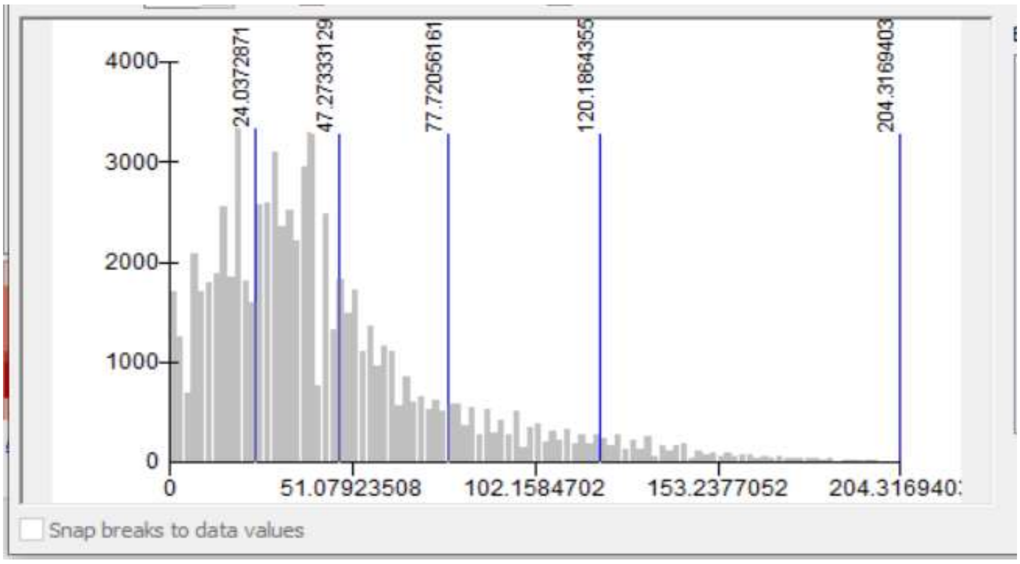


Figure 11: Histogram Showing the Natural Break Classes as used in the Raster Model

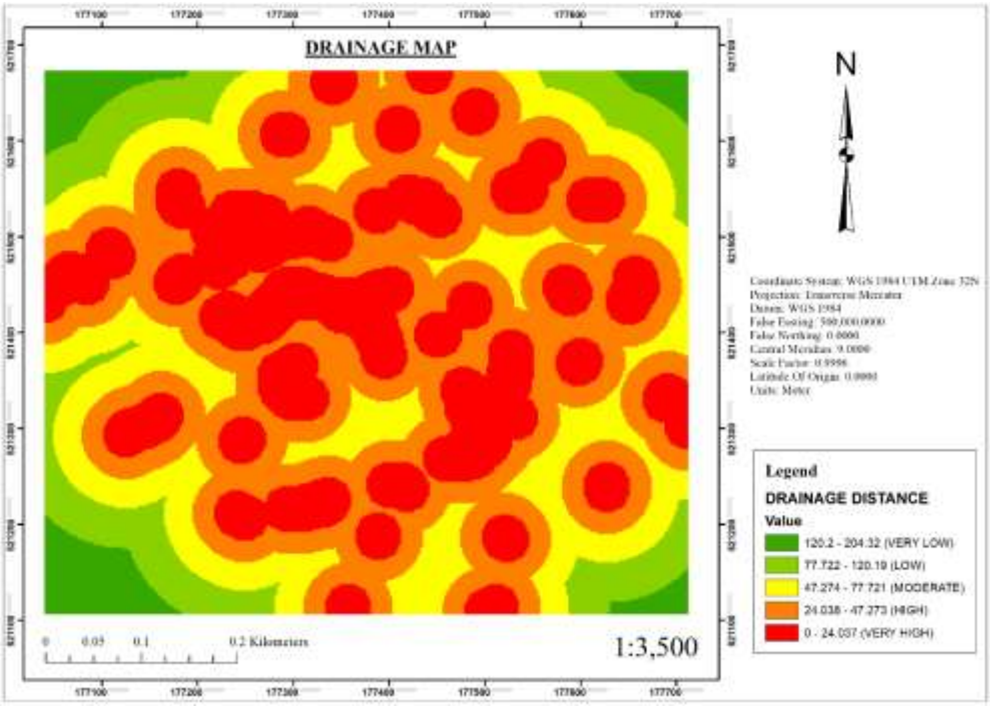


Figure 12: Distance from Drainage Map

Table 4.9 ***Calibration and Weight Evaluation of the Factors Affecting Flood Risk Areas***

FACTOR	**DOMAIN OF EFFECT**	**DESCRIPTIVE LEVEL (FLOOD HAZARD)**	**PROPOSED WEIGHT OF EFFECT (a)**	**RATE (b)**	**WEIGHTED RATING (a x b)**	**TOTAL WEIGHT**	**PERCENTAGE (%)**
SOIL	1193	MODERATE	5	3	15	15	3.67
DISTANCE FROM DRAINAGE	120.2 - 204.32	VERY LOW	1	4.5	4.5	117	28.61
	77.722 - 120.19	LOW	2		9		
	47.274 - 77.721	MODERATE	5		22.5		
	24.038 - 47.273	HIGH	8		36		
	0 - 24.037	VERY HIGH	10		45		
ELEVATION	20.474 - 21.33	VERY LOW	1	4.5	4.5	117	28.61
	21.331 - 21.601	LOW	2		9		
	21.602 - 21.889	MODERATE	5		22.5		
	21.89 - 22.152	HIGH	8		36		
	22.153 - 22.702	VERY HIGH	10		45		
SLOPE (PERCENT RISE)	4.277 - 8.719	VERY LOW	1	2	2	52	12.71
	2.261 - 4.277	LOW	2		4		
	1.201 - 2.261	MODERATE	5		10		
	0.553 - 1.201	HIGH	8		16		
	0.00527- 0.552	VERY HIGH	10		20		
FLOW ACCUMULATION	0 - 40	VERY LOW	1	1.5	1.5	39	9.54
	40 - 176	LOW	2		3		
	176 - 483	MODERATE	5		7.5		
	483 - 1189	HIGH	8		12		
	1189 2221	VERY HIGH	10		15		
PRECIPITATION	2254.133 - 2254.355	VERY LOW	1	1.5	1.5	39	9.54
	2254.356 - 2254.578	LOW	2		3		
	2254.579 - 2254.804	MODERATE	5		7.5		
	2254.805 - 2255.036	HIGH	8		12		
	2255.037 - 2255.313	VERY HIGH	10		15		
LAND USE	7	HIGH	8	3	24	30	7.33
	15	LOW	2		6		
SUM						409	100

4.8 Flood Hazard Map

The calibration and determination of the weights of the factors (Table 9), a multi-criteria evaluation was used by utilizing the specific weights for each factor, for creating the flood hazard map after superimposing the thematic maps with different weights in a GIS environment, the result of a flood hazard map showing the most vulnerable areas to flooding within the main campus. The results showed that a 30.76% of the total study area was prone to "high" and "very high" flood hazards, these areas were flat areas generally laying at low elevations, 39.623% of the study area was prone to "low" to "very low" flood hazards, 29.62% to "moderate" level of flood hazards, most of these areas tended to be on the higher grounds and further away from the high drainage density areas. Table 10 showed the summary statistics computed for each hazard class.

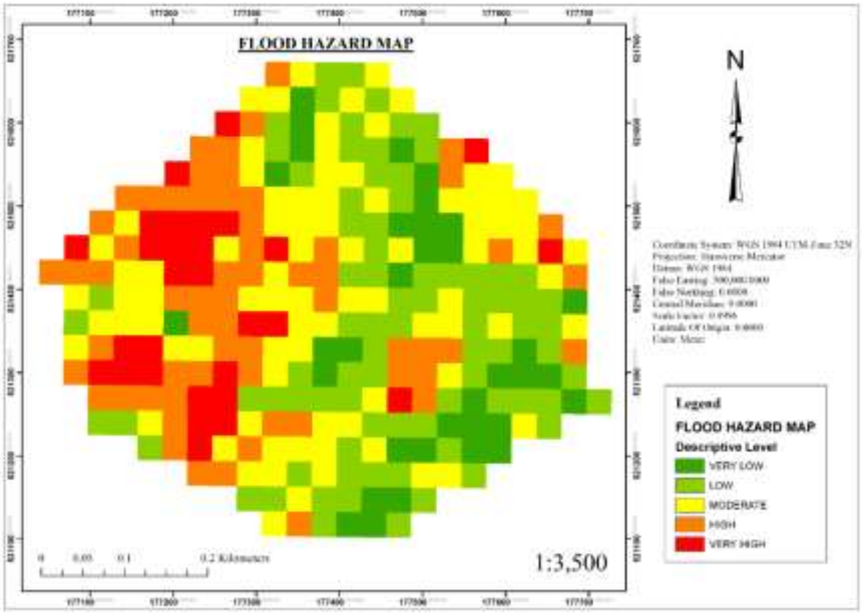


Figure 13 Flood Hazard Map

The result indicated that about 10.064% of the land area was demarcated as very high, 20.696% as high, 29.62% as moderate, 27.71% as low, and 11.91% as very low flood-vulnerable zones (Table 10). Areas with high to very high vulnerability were mainly located along the northwest of the study area (Figure 13). These high to very high flood-prone areas were characterized by lower slopes, lower elevations, and high rainfall intensities, which are important moderating factors for flood risk mapping.

Table 10: Flood Vulnerability Zones

Flood vulnerability zones	Flood vulnerability index	Area	
		SQ. MTS	%
Very High	751.544 – 871.690	26,277.083	10.064
High	674.729 – 751.544	54,033.873	20.696
Moderate	597.915 – 674.729	77,322.946	29.616
Low	509.282 – 597.915	72,344.736	27.710
Very low	369.440 – 509.282	31,103.440	11.913

4.9 Validation of the Flood Hazard Map

To perform the validation of the flood hazard maps results, the locations of the historical flood events were generated based on field inspection information, providing relevant information concerning flooding sites (Figure 14). The details features (Buildings and roads) in the study areas were overlaid on the modelled output. Table 11 showed the list of these historical flooded facilities, and the location of the respective modelled flood vulnerability zones. All historical facilities in Table 11 were located on the high and very high flood vulnerability zones, according to the modelled output which indicated the reliability of the flood vulnerability model used in this study.

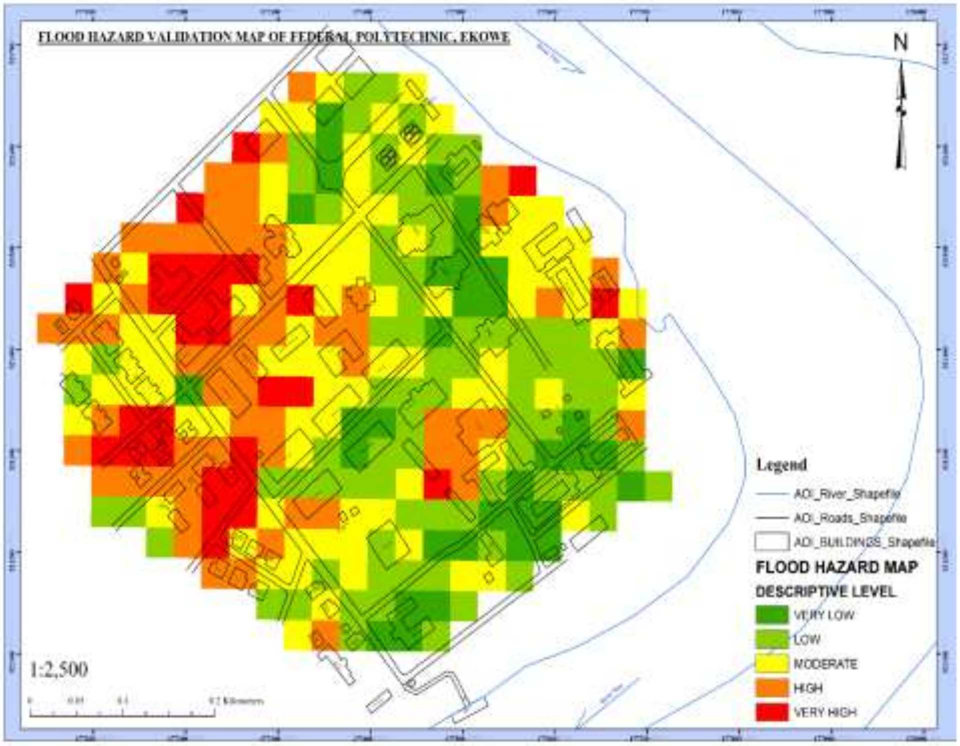


Figure 14: Flood Hazard Validation Map

Table 4.11: Historical Flooded Facilities/Area and Their Position on the Modelled Flood Vulnerability Zone

FLOOD VUNERABILITY ZONES	FACILITIES	NUMBER OF BUILDINGS	PERCENTAGE (%)
VERY HIGH	Rectors 'Residence Service Quarters Girl's Hostel A, B & C Water Supply Facilities Two 3 Bedroom flat Three 3 Bedroom flat ICT Departmental block Old Classroom Boys Hostel A Boys Quarters	20	39.2

5.0

HIGH	Administrative Block Library Classroom Central store Students Centre Cafeteria New Workshop Works ICT	9	17.65
MODERATE	Boys Hostel A and B Old existing Laboratory Old GTC buildings Academic Planning Office Clinic CSO Office Workshop 1,2,3 Security building	12	23.5
LOW	Helipad 1 Guest House Lecture theatre 1 Old clinic Laboratory	5	9.8
VERY LOW	Lecture theatre 2 New workshop 1,2 Boys Hostel D Works physical planning department	5	9.8

Recommendation and Conclusion

5.1 Recommendation

Based on the study, the following recommendations were necessary:

1. Main Canal: The institution has secondary drainage which are inadequate in discharging flood water therefore the study carefully proposed the construction of the main canal, more secondary drains, and the french drain. These factors if properly put in place will reduce the risk of damage and protection of the critical infrastructures.
2. The incorporation of erosion control measures, such as slope stabilization and vegetation management, enhances the overall effectiveness of the campus.
3. The reclamation of low-lying areas for sustainable development and economic growth.

5.2 Conclusion

The estimation of the flood hazard areas is a fundamental component of a flood management strategy, the proposed approach was applied to the study area to determine the areas in danger of flooding. Multi-criteria evaluation methods have been applied in many studies and have proved to be a very successful tool in aiding decision-making processes, seven different input maps were prepared, which were rainfall intensity, elevation, slope, land use, flow accumulation, geology, and distance from the drainage network. Finally, the modelled output maps like floods Hazard map, validation map, the obtained results were validated against historic flooded facilities/areas in the campus. It was confirmed that remote sensing and GIS techniques was proven to be very useful in identifying flood vulnerability zones and to prepare flood susceptibility map. It has also proved that the multi-criteria analysis approach could help provide useful and important information for better management of floods.

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