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Determining Flood Prone Areas in Edo State Using Geographic Information System (GIS) and Remote Sensing

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Abstract

Flooding is a natural occurring disaster that occurs when a usually dry area becomes submerged in water due to heavy rainfall, melting snow, or overflowing rivers. It can cause extensive damage to property, infrastructure and pose risk to human lives. This study employs Geographic Information Systems (GIS) and Remote Sensing methods to evaluate flood-prone areas in Edo State, Nigeria. Eight flood determining factors such as elevation, rainfall, distance to road, distance to river, land use land cover, soil texture, slope factors and drainage density were computed, mapped, weighted and overlaid together to identify and map potential flood prone areas in the study area. The result show that the slope factor in the southern and Central region of the study area is low compared to the other regions, which increase the susceptibility of flooding in that area. The southern part of the study area has low elevation factor, hence will easily be prone to flooding. Likewise, the southern part of the study area has higher amount of rainfall relative to other part. The result revealed that most part of Edo state is prone to flooding. Policymakers, emergency and other relevant agencies should be effective in deploying resources for disaster preparedness, mitigation, and response operations

1. Introduction

Flooding is expressed as surplus of water in a place that is naturally dry [23]. It might be seen as a relatively spill of water over the banks of surface water bodies like river. Flooding can also be considered as an outpouring of water that comes from river, reservoirs, lakes etc. and bring about destruction to lives and properties [20]. It is a condition of partial or wholly submergence of an area due to spill over from sporadic and speedy buildup of runoff [22]. It is probably the most damaging, common, and frequent natural hazard in the world [3].

A flood happens as soon as water in a river or any water bodies flows out its boundaries and submerges nearby areas [23]. Some of the factors resulting to flood disaster include throwing away of solid wastes in drains and on the floodplain (Sarah 2007) cited in [21] (2016). [13] (2000) reported that uncontrolled urbanization such as building along flood plains, unrestrained advancement of structures into flood plains alongside massive road construction with largescale land recovery that result to flood disaster. Since deforestation, urbanization, and climate change are all variables in the intensity and frequency of flooding, it is imperative to understand the causes, effects, and preventive measures of flooding [24]. Floods may cause catastrophic, long-lasting damage. Floods have a number of direct effects, including the loss of life, devastation of property and infrastructure, and disruption of transportation and communication systems. Additional significant economic repercussions of floods may include lost wages, lower output, and greater insurance costs. [8]. In addition to their short-term effects, floods can also have long-term repercussions on the ecosystem. Floods can affect farmers and farmland thereby affecting livelihood [18]. Therefore, there is need to determine places prone to flooding, so as to enhance the general wellbeing of the people. This could be done using Geographical information system.

While several authors have analyzed flooding within Edo State [18]; [19], there is still inadequacy in the adoption of geospatial (Remote Sensing (RS) and Geographic Information System (GIS)) technology for flood-risk assessment. GIS and RS techniques offer robust flood disaster forecasting and occurrence prediction tools. They have effective and reliable tool that provides valuable guidance aimed at solving flood disasters [9]. Actions geared towards solving flood disasters could only be successful with a proper flood vulnerability map. Several authors have used GIS and RS techniques in flood vulnerability in Nigeria [2]; [5]; [17].

2. Materials and Methods

2.1 Description of the Study Area

This research was conducted in Edo state, Nigeria. Edo state as shown in figure 1 below is situated in southern Nigeria between latitudes 050 44' N and 070 34' N, and its longitude is 050 04' E. Ondo state borders it on the west, Delta state borders it on the south, Kogi and Anambra states border it on the east, and Kogi state borders it on the north. The River Niger runs beside Edo state's eastern border. In the state of Edo, there are other River Niger beaches at IIushi and Ise Lake as well as Agenebode, Etsako-East. The State is also characterised by high rainfall with July having the highest mean rainfall (403.0mm) while the month of January recorded the lowest (17mm).

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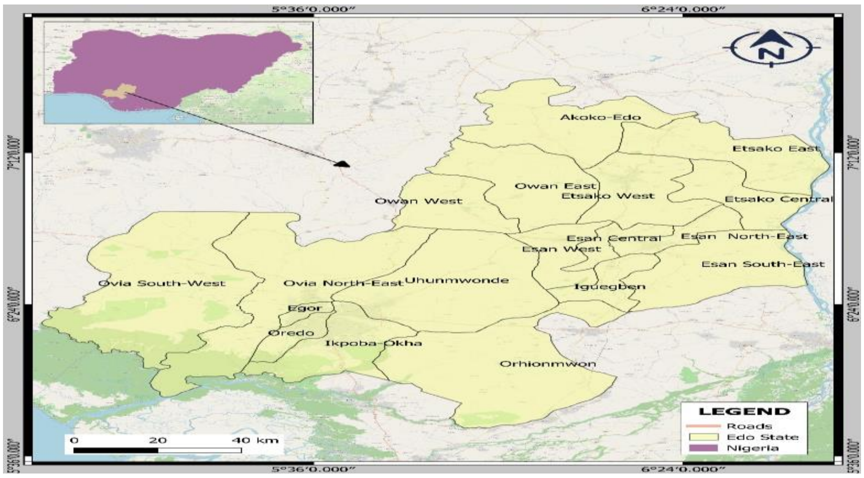

Figure 1. Map of Edo State, Nigeria**.**

2.2. Methods of Data Collection

This study adopted multi-criteria analysis as depicted in Figure 2 below. The flood risk analysis was analyzed using several criteria which includes Land Use Land Cover, distance to road/river, slope, elevation, drainage density and soil texture.

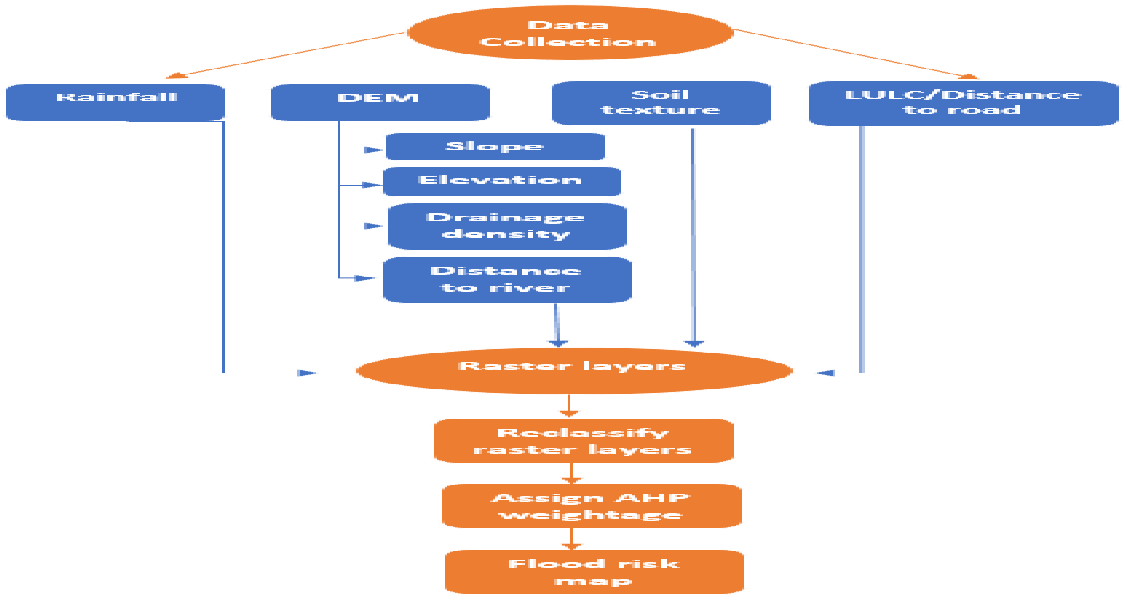

Figure 2: Work flow

2.3 Flood Risk Mapping Method

All data are secondary and were pre-processed using ArcGIS 10.8. Firstly, all raster data for each criterion were classified into four groups (High, Moderate, Low and Very low) which were later reclassified assigning number 1-4 from very low to high. Weighting strategies play a pivotal role in assessing the significance of individual factors concerning one another. By employing weighted sum techniques, each factor's relative importance was ranked, with higher weights signifying greater importance compared to other factors. The culmination of this process is the development of a comprehensive flood hazard map. To elaborate, weighting strategies allow decision-makers to assign numerical values to different factors that contribute to a particular outcome or analysis.

3. Results and Discussions

3.1 Results

Slope Factor

According to the slope map of the study areas as shown in figure 3below, regions with higher slope values such as the Northern areas of the State with the value of 493,500 – 1,516,000 will have a lesser case of flooding as opposed to the southern area which have a lower slope value of 0 – 89,170.

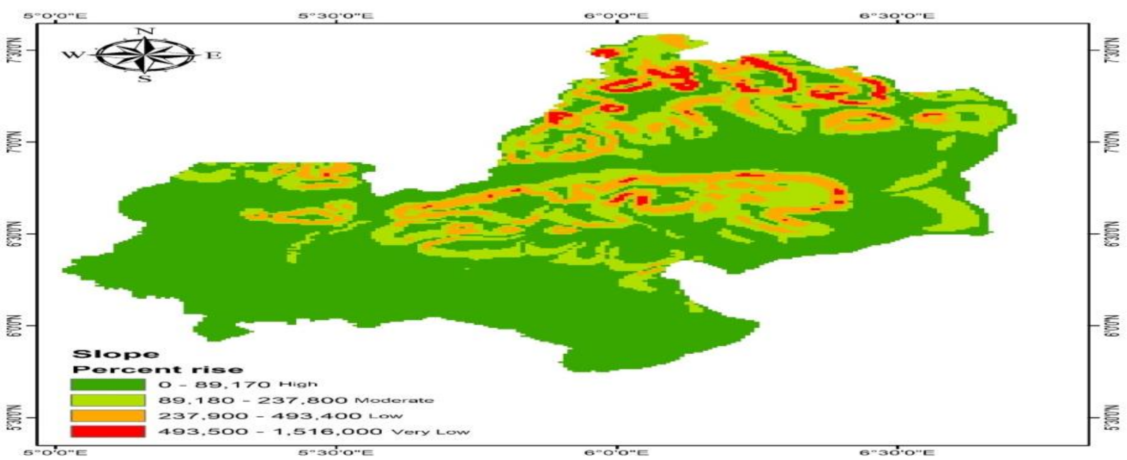

Figure 3: Slope Map of the study area

Elevation

The district's low-lying sections, which stretch from its southern to southwestern corners, as depicted in Fig. 4 below are particularly susceptible to flooding. However, some regions, like the Northwestern portion of the study area, have minimal to very low flooding risk according to the elevation map of the study area. Greater portion of the study area have low elevated areas which contributes to the high susceptibility of flooding in the area. The elevation map of the study area was divided into four classes (High, Moderate, Low and Very low).

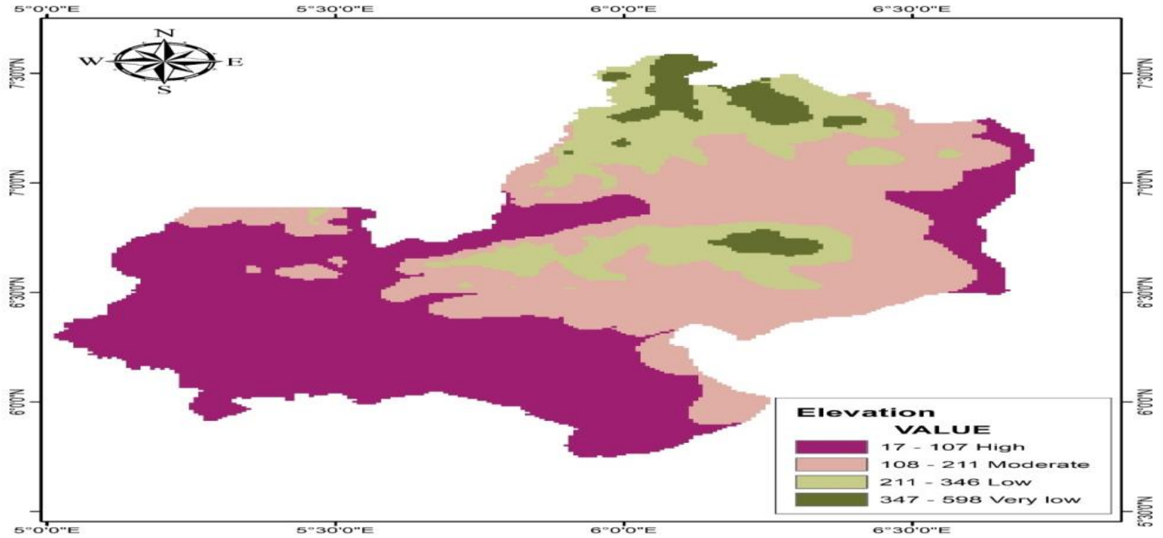

Figure 4: Elevation map of the study area.

Proximity to River

In this study, four categories were obtained with regards to proximity to river, namely high (0- 3,970 m), moderate (3,980-9,550m), low (9,560-17,400m) and very low (17,500- 31,600m) as shown in figure 5 below. The southwestern to southeastern part of the study area has a high to moderate proximity to river (0- 3,970 m, 3,980- 9,550m) thereby making it more susceptible to flooding.

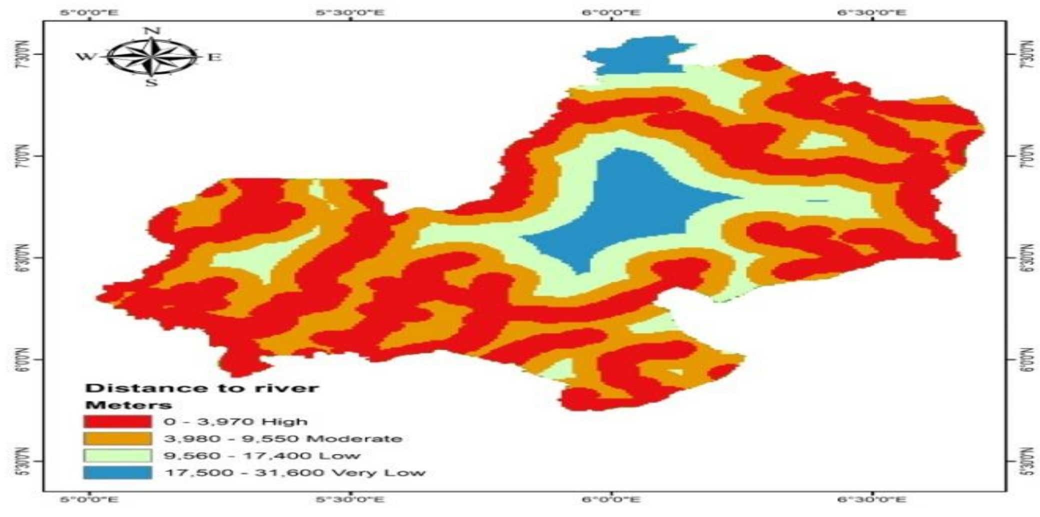

Figure 5: Proximities to rivers in Study area**.**

Rainfall

As shown in figure 6 below, the southern region of the study area have a high level of rainfall (2,262.61mm- 2,838.8mm), in contrast to areas in the northern part of the study area with very low rainfall.

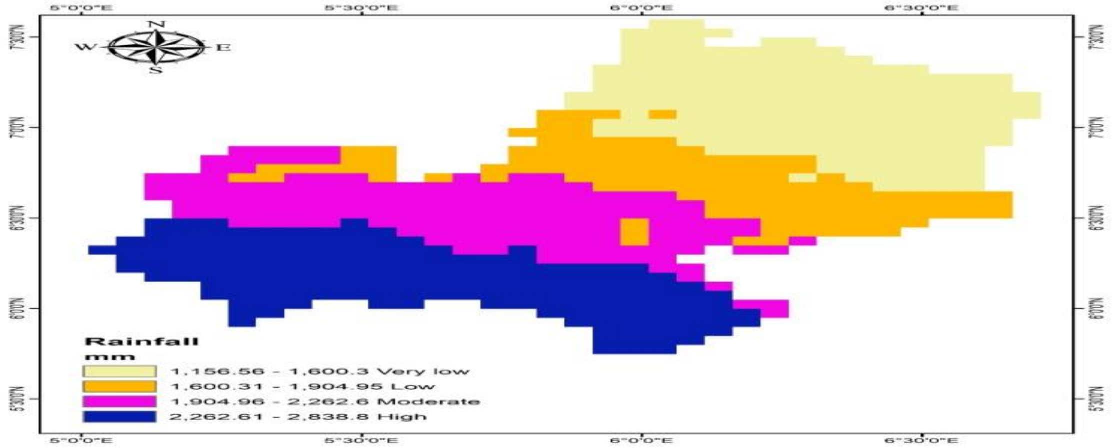

Figure 6.: Rainfall distribution in the Study area.

Soil texture and Drainage

Soil texture of the study area as shown in figure 7 below are classified as clay loam, sandy clay, sandy, sandy loam and silty loam. About 57.38% of the study area is characterized by sandy loam, the rest 16.56% and 26.06% of the study area is covered with silty loam and sandy clay soil texture respectively, According to the soil drainage map figure 5b, it shows that the southwestern part of the study area is well drained. However, the southwestern part of the study area is predominantly covered with sandy loam soil, which is a soil texture that is prone to flooding because of its high permeability.

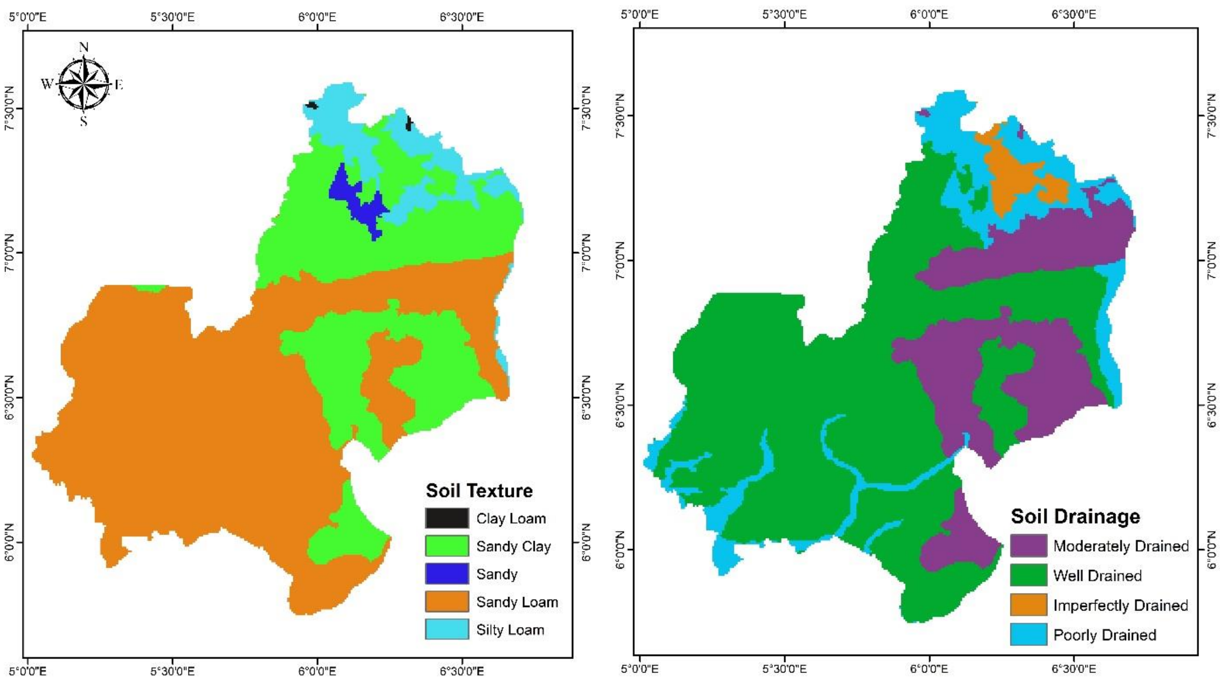

Figure 7a and 7b: Soil Texture and soil drainage map of the study area**.**

Land Use Land Cover (LULC)

The LULC map of the study area in this study is categorized as high (forestland), moderate (cultivated/grassland), low (built - up), and very low (water) susceptibility to flooding as shown in table 1and figure 8 below. Forestland is the major LULC type of the district covering a high to moderate part of the study area. Land use land cover analysis is pivotal for flood risk analysis as it depicts the current ground situation of the study area.

Table 1. Classification of Land Use Land cover of the study area.

Category	Classification	Kilometers
1	Water	Very low
2	Built up	Low
3	Cultivated/grassland	Moderate
4	Forestland	High

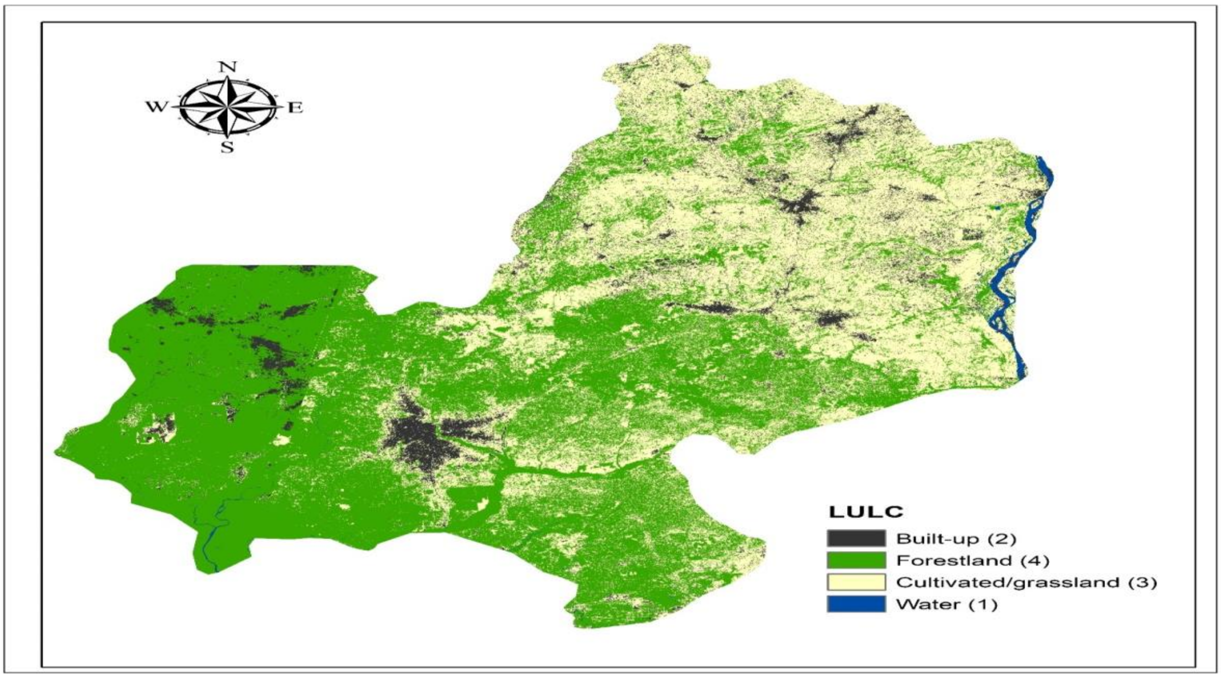

Figure 8: LULC of the study area

Drainage density

Drainage density is an important metric since it shows a catchment's potential for runoff. A greater drainage density suggested a greater possibility for runoff. It was projected that larger part of the study area is susceptible to flooding due to the low drainage density. The drainage density of the study area was classified as very low, low, moderate, and very high flood hazard zones, as shown in table 2 and figure 9 below.

Table 2: Classification of the Drainage Density of the Study Area.

Range	Category	Classification
0 – 291.032	1	Very low
291.033 – 820.181	2	Low
820.181 – 1,508.07	3	Moderate
1,508.08 – 3,373.32	4	High

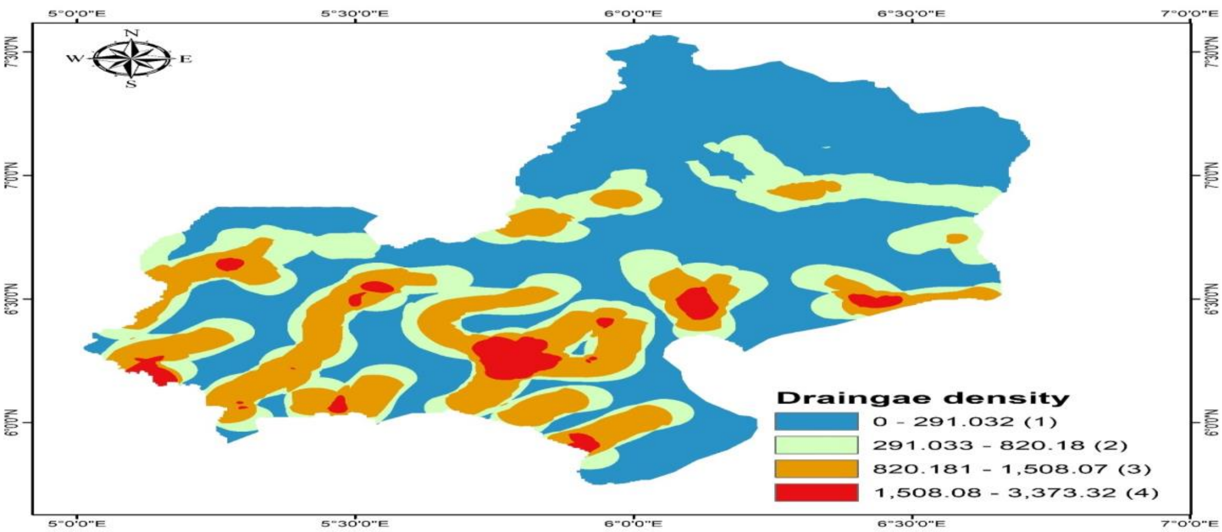

Figure 9: Drainage density map of the study area**.**

Flood Probability

The final flood susceptibility map for the state of Edo was created by combining eight thematic maps representing flood-controlling elements, as seen in table 3 and figure 10 below. The district was divided into four flood susceptibility classes using the weighted overlay integration: high (4), moderate (3), low (2), and very low (1) susceptibility. Larger part of the study area showed moderate to high flooding susceptibility. The majority of the study area's southern and southwestern regions are the areas that are most susceptible to flooding, based on the flood susceptibility map.

Table 3: Flood probability table.

Category	Square	Kilometers
1	3707.0199382	Very low
2	5710.8285940	Low
3	4590.6900727	Moderate
4	4818.7101420	High

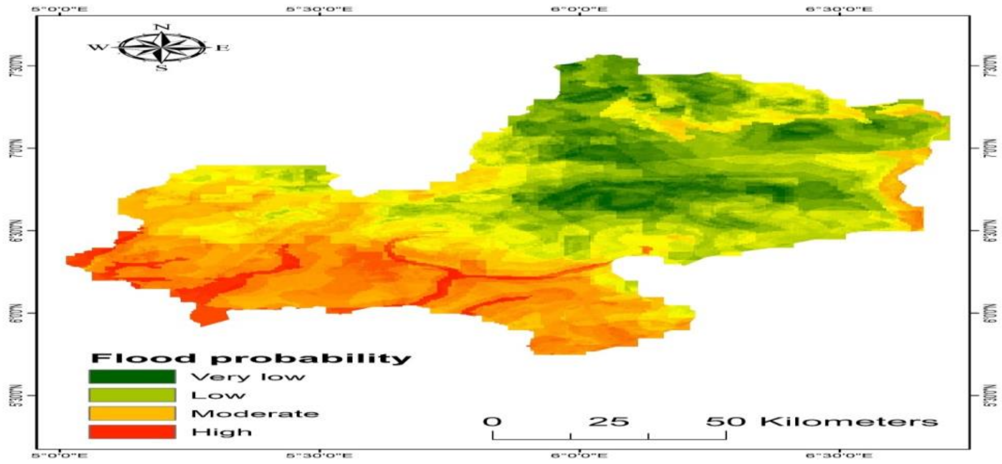

Figure 10: Flood susceptibility map of the study area.

3.1 Discussion

This study evaluated areas prone to flooding in Edo state, Nigeria. The study's eight flood-controlling variables, including elevation, slope factor, distance to rivers and road, rainfall, drainage density, land use and land cover, and soil type, were utilized to map and identify possible flood-prone locations. These characteristics were investigated and analysed in order to identify and map using GIS the spatial distribution of flood vulnerability in the study area. Below are further specifics on the analysis of each element.

Slope factor

According to the slope map of the study area, the slope of most part of the study area is low. Locations with high slope are found in few places of the northern part of study area. Basically, the speed of surface water flow is governed by the slope of the terrain. The volume of water covering the land increases along with the likelihood of a flood as the slope falls [7]; [10]. Lowlands or flatlands with mild slopes have a higher likelihood of flood inundation, but mountainous locations typically have steeper slopes that hinder the gathering of water [25]. Infiltration of water into the earth is typically reduced by steep slopes, allowing for speedy overland passage of the water to rivers. Additionally, steep slopes increase the throughfl ow of soil. Areas with steeper slope tend to have lesser case of flooding compared to areas with gentle slope. Higher slope values indicated steeper topography that is less susceptible to flooding, whereas lower slope values indicated flatter topography that is more sensitive to flooding.

Elevation

The district's low-lying sections, which stretch from its southern to southwestern corners are particularly susceptible to flooding. However, some regions, like the Northwestern portion of the study area, have minimal to very low flooding risk due to the elevation. Greater portion of the study area is low which can increase susceptibility of flooding in the area. Elevation is one of the elements considered when determining flood risk because lower elevated areas have a relative higher river discharge and flood more quickly when high water is flowing. They typically have a higher probability of experiencing floods than higher elevated areas [12].

Distance to River/ Distance to Road

The study area was divided into four categories based on its vulnerability to flooding, with regards to proximity to river and road. Namely high (0- 3,970 m), moderate (3,980-9,550m), low (9,560-17,400m) and very low (17,500- 31,600m). The southern part of the study area has a high to moderate proximity to river and to road networks which increase its susceptibility to flooding more than other part of the study area. Rivers could overflow their banks thereby causing flooding to locations closer to them when they receive excess water. If human settle or carry out their activities closer to road, there is that tendency for both natural and manmade waterways to be obstructed or silted thereby causing flooding to adjoining areas. This is true since excess water from rivers could overflow their banks and nearby lowland areas. As such, areas close to rivers have a higher likelihood of flooding than areas faraway as asserted by [16] (2018). In a similar studies done by [10] (2021) it was revealed that places of 500, 1000, 1500, 2000, and > 2000m from the river were rated as having very high, high, moderate, low, and very low susceptibility to flooding, respectively.

Rainfall

Since we cannot imagine a flood occurring without rainfall, it must be taken into account while analyzing flood susceptibility. Because flood disaster results from a significant amount of runoff flows as a result of excessively heavy rainfall or protracted rainfall, it is the most important component that causes flooding [12]; [6] and [19]. In Edo State, there is an average of 2284.5mm of rainfall with 265.91 of those days (or 77.85% of the time) experiencing rain fall. Due to the high amount of rainfall in most part of the state, particularly in the central and southern part, the study area can be said to be susceptible to flooding. Rainfall intensity is an important factor causing flooding. The higher the amount of rainfall, the greater the tendency for flooding to occur. The capacity to cope and preparedness to flood disaster in the study area is low [18].

Soil Texture

The study area is predominantly sandy loam which could allow water to drain speedily. But the study area has high amount of rainfall annually which could cause water to be retained on the soil for a while, thereby causing flooding. The nature of the soil has a significant impact on the infiltration process. The soil's fine texture composition enhances surface runoff and decreases infiltration. The likelihood of flooding is therefore higher in places with fine soil texture than in locations with coarse soil texture [12]; [6]; [11]. The area's ability to hold water and the rate at which rainfall infiltrates are both greatly influenced by the type of soil present. Therefore, it may be regarded as one of the crucial elements in determining flood-prone places. Due to the larger pore space between soil particles, sandy soils have higher saturated hydraulic conductivities than soils with finer grained textures. Different soil textures have varying water absorption capacities; infiltration significantly affects the amount of surface runoff generated by the rainfall. Water penetrates substantially more slowly in clay soil than sandy soils. When creating the soil texture factor, consideration was given to the physical properties of the soil, particularly its texture. Sandy loam predominately covers the study area.

Land Use Land Cover (LULC)

The LULC of the study area is categorized as high (forestland), moderate (cultivated/grassland), low (built - up), and very low (water). Forestland is the major LULC type of the district covering about 71.72% of the study area. With regards to susceptibility to flooding, the built-up areas, cultivated grassland and areas close to water bodies are more prone to flooding in the study area. However, forestland is less prone to flooding in the study area. Land use land cover analysis is pivotal for flood risk analysis as it depicts the current ground situation of the study area. Land use/cover classes such as built-up, forest land, grassland and surface water are incorporated to predict flood-prone areas. When assessing flood-prone locations, land use and land cover are crucial considerations. They affect how water interacts with the surface of the land and how runoff from rainfall is controlled [14]; [6]; [10]. Urban environments with a high proportion of impermeable surfaces, such as parking lots, buildings, and highways, are less water permeable. When it rains, water cannot permeate the ground effectively and instead quickly rushes off, tasking drainage systems and raising the risk of flooding. Greater vegetation, greenery, and natural landscapes are better at absorbing water than other types of land use. The retention of precipitation by trees, grasslands, and wetlands can help to delay runoff and lessen flooding. In locations prone to flooding, preservation of these natural habitats is essential. [6] (2021) considered shrub land, cropland, bare land, urban, and waterbody as very low, low, moderate, high, and very high susceptibility to flooding, respectively. Das and Gupta (2021) categorized waterbody, build-up, agriculture, sparse vegetation, and dense vegetation as very high, high, moderate, low, and very low vulnerability to flooding, respectively. [11] (2022) also classified built-up areas, farmland, grassland, shrubland, and forestland areas as extremely high, high, moderate, low, and extremely low vulnerability to flooding, respectively.

Drainage Density

The quantity and distribution of natural or man-made channels, such as rivers, streams, and storm water drains, within a specific area is referred to as drainage density. It is frequently stated as the sum of streams' or channels' lengths per square kilometer, for example. High drainage density can worsen flooding in flood-prone areas, whereas low drainage density can lessen the risk of flooding. However, when it rains, areas with higher drainage density have more natural or man-made channels to divert surplus water off the surface of the ground. Because of the effective conveyance and discharge of water into bigger bodies of water, like rivers or lakes, this high drainage capacity might lessen the likelihood of flooding. Water may collect and be kept on the soil surface for prolonged periods of time during heavy rainfall in locations with low drainage density. Increased flood risk may result from this retention, particularly if the soil is already wet or if the land is flat and devoid of natural outlets for water runoff. The drainage density can be described as the proportion of a region's total length of streams to its total area [26]. The likelihood of flooding increases with drainage density [1]; [10]; [15]. Surface runoff also increases with drainage density. According to a study by [4], areas with drainage densities of less than 0.45 km/km2, 0.45-1.01 km/km2, 1.01-1.64 km/km2, 1.64-2.47 km/km2, and greater than 2.47 km/km2 were assessed to have very low, low, moderate, high, and very high sensitivity to flooding, respectively. In this study, the result reviewed that greater part of the study area is drained. This makes the study area to be susceptible to flooding. As more water from the drainage system (rivers, stream, pond, lakes etc.) could overflow to adjoining lands close to them. Since it directly affects the likelihood of flooding during periods of heavy rainfall, drainage density is an important consideration when assessing flood-prone areas.

Flood Probability

Based on the flood probability, approximately 86.83% of the study revealed moderate to high susceptibility to flooding. The other 13.17% indicated low to extremely low flooding susceptibility. The majority of the study area's southern and southwestern regions are the areas that are likely to be susceptible to flooding. This could be attributed to the fact that greater part of the study area is well drained and the slope is low. Furthermore, rainfall another contributing factor to flooding is equally relatively high in the greater part of the study area notably the central and southern part.

4. Conclusion

Flooding is a natural occurring disaster, but some factors can further enhance the occurrence of flooding, these factors include the topography of the area and amount of rainfall. Unarguably excessive rainfall is one of the major causes of flooding. Edo state is one of the states in Nigeria prone to flooding due to its topography and amount of rainfall. This study was carried out to evaluate areas prone to flooding in Edo state, Nigeria using the integration of Geographic Information System (GIS). The result showed that about 78.39% and 8.39% of the study area experienced high to moderate susceptibility to flooding respectively. The remaining 13.17% of the study area is characterized by low to very low susceptibility to flooding. Therefore, greater part of the study area is prone to flooding. Therefore, government and other stakeholders should ensure proper drainage channeling are placed in those areas prone to flooding, so as to combat the risk of flooding. Also afforestation should be encouraged, because plants can reduce the intensity of surface runoff.

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