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Geospatial Mapping of Areas Vulnerable to Flooding in Ado-Ekiti, Ekiti State, Nigeria

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ABSTRACT

Flood damage is always very serious, often leading to economic and cultural losses. There are many records of flooding in Ado-Ekiti. The aim of this study is to map areas vulnerable to flooding in Ado-Ekiti using geographical information system (GIS) and remote sensing. Data used for the research include IKONOS imagery, digital elevation model (DEM) and field survey. The imagery was classified into Landuse Landcover (LULC) as follows: vegetation, water body, plantation, built-up area and bare land. DEM was used for analysis of slope, elevation and flow accumulation. Three scenarios were used to generate flood vulnerability maps. In scenario one, computed percentage influence of vulnerability factors was used and it showed that less than 1% of the entire study area falls under very high vulnerability which includes such areas as EKSUTH, Textile and Igirigiri. From scenario two, areas like GRA, Odo-Aremu, Ekute, Omisanjana, Ajebamidele, Ureje with high vulnerability accounted for about 20.09% of the study area while scenario three recorded that areas like Moferere and Adebayo falls within the 59.26% areas with moderate vulnerability. It can be concluded that the use of scenario in vulnerability study will yield results that can assist policy formulations geared towards preventing the occurrence of flooding or reducing their effects. Areas with high vulnerability in the study area include GRA, Odo Aremu, Ekute, Omisanjana, Ureje, therefore, government should focus more attention on these areas.

1. INTRODUCTION

Flood damage is always very serious and severe. It has been reported to be the leading cause of losses from natural hazards and is responsible for a greater number of damaging events than any other type of natural event (Alcira and Martha, 1991; Ologunorisa, 2001). Floods occur both in the developed or developing world

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and are always associated with heavy loses of lives and properties, misery, hardship, diseases, and at times, famine (Ebuzoeme, 2015). The United Nation reports that for the past 20 years, about 90% of major disasters are caused by 6,457 recorded floods and other weather-related events (UNISDR, 2015).

Common disasters in Africa vary from locality to locality and ranges from drought in which crops will not grow amounting to famine, flooding, extreme weather events and climate change (IFRC, 2011). Flood menace in Nigeria has become a normal and re-occurring phenomenon which sometimes has devastating impacts on human livelihoods and infrastructural development. In the year 2011 alone about thirteen states of Nigeria experienced flooding of one sort or the other leading to loss of lives and properties. There were records of number of deaths due to flooding in not less than nine states in the year 2014 (Agbonkhese et al., 2014). According to Aderogba (2012), flood accounts for the highest occurring natural hazards in Nigeria and this with great consequences on the life and property.

Flooding has been almost a yearly occurrence in the city of Ado-Ekiti for the past 3-4 years now. Ogundele and Jegede (2011) identified Basiri, Irona, Bawa Estate, Adehun, Omisanjana, Atikankan, Ureje areas of Ado-Ekiti as under threat of flooding. They based their identification on the use of questionnaires distributed to people living in the affected areas but no attempt was made to map the flood vulnerable parts in the town. According to them, there is low rate of infiltration of the soil, as a result of pavements in the areas. This means that, the soil is non-porous and does not retain water and immediately there is rainfall, the surface of the soil will be covered with water, and as such, flood and runoff characteristics occur.

To reduce the reoccurrence of flooding and make cities like Ado-Ekiti free of consequences of flooding will require preparation for both the probability and consequences of flooding. This calls for a new strategic policy that is geared towards effective flood risks management, and an important step towards this integration is the ability to map flood vulnerable areas in the city and strategic visions with short-term actions put in place (Woltjer and Al, 2007).

Vulnerability simply means susceptibility to injury or attack. It is the quality or state of being exposed to the possibility of being attacked or harmed either physically or emotionally. In the context of disaster management, vulnerability can be described as the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard. There are several situations that can increase our vulnerability to disasters. One example is building homes in high-risk areas. For instance, if you live too close to a river and people have been throwing garbage into it so that the water cannot flow on through, you will be more vulnerable to floods.

GIS techniques can contribute to finding out accurately what causes floods and map flood hazard (Uddin et al., 2013). It can together with earth observation techniques be used to assess damage to properties, infrastructures and agricultural products. Remotely sensed data can be employed in identifying the behaviour of river channel and as source of input data for determining behavior of its linking water channels. One of the main characteristics of remote sensing is its capability to generate a large amount of information frequently and spatially, making it a powerful tool for monitoring changing aquatic environments.

Application of GIS and remote sensing technology to map flood areas will make it easy to plan measures which reduce the flood damages and risks involved. It will be of great benefit in implementing a flood management program that consists of flood forecasting and flood hazard and vulnerability mapping.

Ejikeme et al. (2015) used the potentials of GIS combined with Remote Sensing satellite image as a platform for modeling and analyzing environmental phenomenon and for providing sustainable and profitable solutions to environmental management. Okoye and Ojeh (2015) identified the immediate and indirect causes of flooding in Surulere, Lagos state by mapping out the parts of the LGA that are more susceptible to flooding using GIS and proffered solutions to the flooding situation in Surulere. Ojigi et al. (2013) exploited a combination of techniques in carrying out a geospatial mapping and analysis of the 2012 flood disaster in parts of the central states of Nigeria and environs for the effective management of the menace. Korah and Lopez (2015) identified the most vulnerable areas to flooding in the city of Quetzaltenango and proposed mitigation approaches for averting the negative impacts of flooding.

Various studies on flooding have been carried out by different scholars in Ado-Ekiti. Some focused on the environmental influences of flooding on urban growth (Ogundele and Jegede, 2011; Odeyemi et al., 2016), others looked at risk analysis (Komolafe et al., 2015), watershed management and ecological hazards (Arohunsoro et al., 2014), environmental effect of urbanization on river channel (Adebayo and Arohunsoro, 2014). None of these studies tried to map areas vulnerable to flooding in the city and that is the vacuum this research work intends to fill up.

The main aim of this research work is to map areas vulnerable to flooding in Ado-Ekiti using GIS and Remote sensing approach. Factors responsible for flood vulnerability in Ado-Ekiti were identified and spatial analysis of the area was carried out using multi-criteria approach. Finally, maps of areas vulnerable to flood in the area were created at different scenarios.

2. METHODOLOGY

2.1. Study Area

Ado-Ekiti is located within the North Western part of the Benin-Owena River Basin development Area (Figure 1). The town lies between Latitude 07º 34’N and 07º 44’N of the Equator and Longitude 05º 11’E and 05º 18’E of the Greenwich Meridian. It has a number of Satellite towns around it. To the North is Iworoko, about 16 kilometers away from the city; to the East are Are and Afao, about 16 kilometers; to the West are Iyin and Igede, about 20km and to the South is Ikere, about 18 km. Ado-Ekiti enjoys the privilege of being a nodal town and is located at the centre of the state; hence roads that leads to other parts of the state converge in the city. Being a tropical location, the city enjoys the tropical climate with two seasons i.e. the rainy season and the dry season. The two seasons are usually determined by the Tropical Maritime and the Tropical Continental air masses. The mean annual rainfall totals vary between 1200 mm and 1400 mm with over 80% of the rainfall events concentrating between June and early October. Rainfall in the area is highly intensive with between 75% and 80% of the total rainfall consisting of the medium to high intensity occurrences. The soils are highly erodible due to the availability of thick depth of weathered overburden averagely varying in thickness between 0 and 14 m (Adeniyi, 1993).

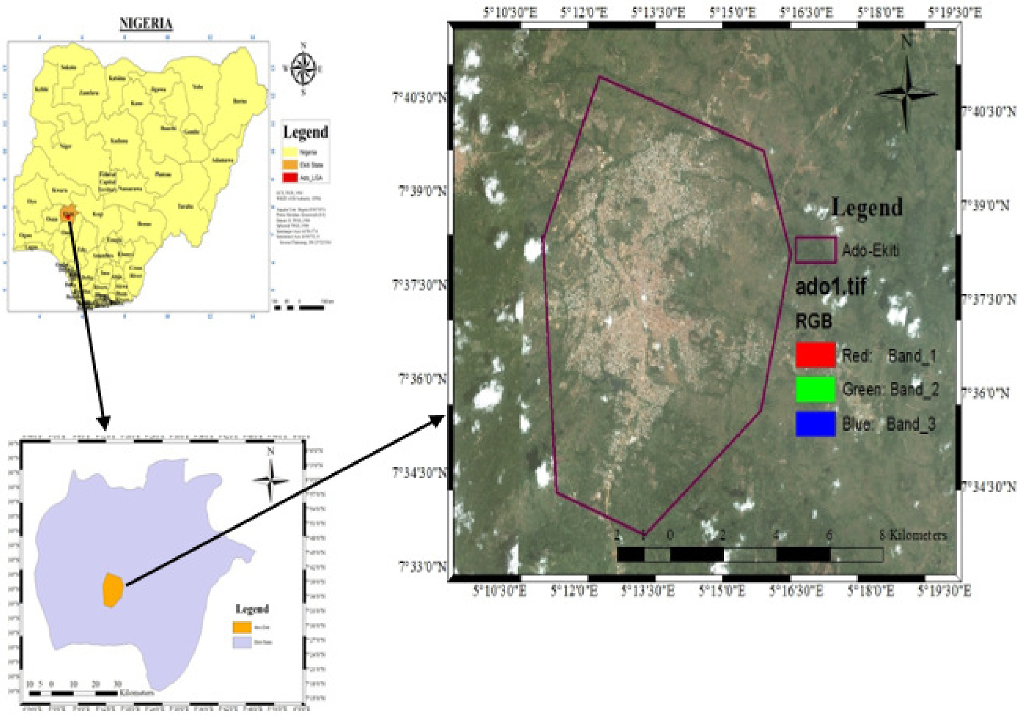

Figure 1: Location of Ado-Ekiti in Ekiti State, Nigeria

2.2. Data Acquisition and Processing

Ground survey technique was used to obtain the X, Y, Z coordinates of some points for referencing purposes. IKONOS satellite imagery of the study area was acquired with resolution of 0.7 x 0.7 in WGS 1984 datum. In the same vein, the digital elevation model covering the area was downloaded from the USGS Earth Explorer. The method employed for this study is illustrated in Figure 2. ArcGIS 10.2.2 was launched and the IKONOS imagery covering the study area initially acquired was added as a raster object. Ado-Ekiti shapefile was created covering the study area on the imagery. This newly created shapefile was then used to clip on the satellite imagery thereby creating an area of interest. The new tiff image of the area of interest was then exported as an image file (i.e. with .img) to ERDAS Imagine 9.2 for further processing. In a similar way, the acquired DEM of Ado-Ekiti was attached to a new map document on the ArcGIS and shapefile of Ado was used to clip this and the file was named adoclip_dem.tiff. This was used in the same package for multi-criteria spatial analysis carried out.

Based on the review of authors who have worked on factors that lead to vulnerability in different parts of the country, factors such as haphazard location of buildings, human occupation of the flood plains, increase in population, rising level of construction activities, generation of waste and illegal methods of refuse disposal, high rainfall amounts, intensity and duration, impermeable layer, construction of roads without adequate drainage channels and lowland topography were identified. Qualitative research strategy (Robson, 2002), was also employed in which the experiences, perceptions and views of relevant professionals was explored. Focused interviews were conducted for three (3) professionals who are knowledgeable in the field of geography, town planning and environmental management on the causes and effect of flooding in an area (Annum, 2017).

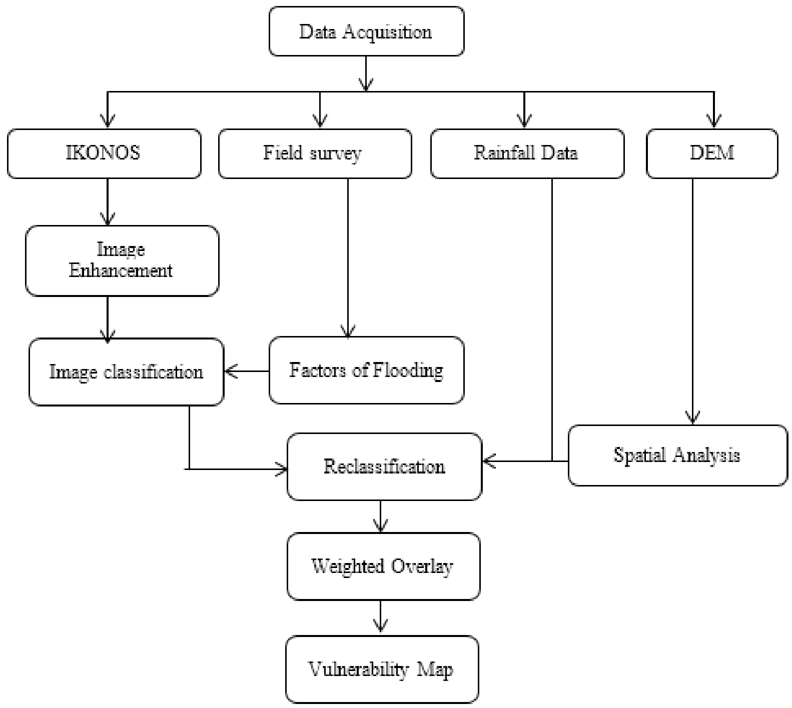

Figure 2: Flow diagram of methodology

The corrected IKONOS imagery was used for classification. Five classes were used based on the observed factors that lead to flooding in the area. These classes include: bare land, built-up areas, plantation, vegetation and water. Terrain analysis was carried out using the clipped DEM and imagery of Ado-Ekiti. The following spatial analyst tools were used to achieve the desired results, slope tool, fill tool, flow Direction tool and flow Accumulation tool.

The result of analysis of twenty years rainfall data shows that rainfall values for the study area ranges between 9mm and 235mm per annum. Climate data of the study area was downloaded from en.climate-data.org for the rainfall intensity distribution. This ranges from 111.15 - 153.74 the difference of which was divided into three aspect to describe high vulnerability, moderate vulnerability and low vulnerability. In each case a reclassification of other factors was carried out to experiment how these factors changes with different level of rainfall intensity. According to a study carried out by Adeniyi (1993), the soils of the Ado-Ekiti are highly erodible due to the availability of thick depth of weathered overburden averagely varying in thickness between 0 and 14metres. This assertion was adopted i.e. the entire Ado-Ekiti is vulnerable to flood if it was to be based on soils factor. Therefore, this factor was considered constant for all areas within the study area as a factor that is responsible for vulnerability in the area.

In mapping the areas vulnerable to flood in the study area, five factors were considered and these are; land use, flow accumulation, slope, elevation and rainfall intensity (which was only used in the final risk map). The first thing was to assign weight to each of this factor before using an overlay tool to create the vulnerability map based on the assigned factors. The relationships between five factors of vulnerability (See Table 1) used in this study were derived using the method of Shaban et al (2006) and Ozkan and Tarkan (2015). This relationship was used to calculate each factor's rate as the sum of the impacts on others. After this the weight and ratios of each factor were combined by associating with each other. This approach involved multiplying the calculated ratio and its determined weight to calculate the total weight for each factor. A scale 1 – 5 was used so as to have equal divisions that will aid summing and normalization appropriately. Scale 5 was assigned to Very High Vulnerability, scale 4 to High Vulnerability, 3 to Medium Vulnerability, 2 to Low Vulnerability and 1 to no Vulnerability.

Table 1: Relative rates for each vulnerability factor (Modified from Ozkan and Tarhan, 2015)

Factor	Interaction between factors	Rates	Outcome
Elevation	3 major + 1 minor	(3x1) + (1x 0.5)	3.5 points
Slope	2 major + 0 minor	(2x1) + (0x0.5)	2.0 points
Land use	1 major + 1 minor	(1x1) + (1x0.5)	1.5 points
Flow accumulation	1 major + 1 minor	(1x1) + (1x0.5)	1.5 points
Elevation	1 major + 1 minor	(1x1) + (1x0.5)	1.5 points

The Reclassify spatial analyst tool was used to reclassify the five vulnerability factors that affect flooding such as the slope, flow accumulation, land use and rainfall into a common scale factor on the basis of Jenk's Natural Breaks methods (Smith, 1986; Skelton and Panda, 2009). Weighted overlay analysis was done to overlay the classified thematic maps of slope, flow accumulation, elevation, land use and rainfall intensity in order to produce the final vulnerability map of the study area. Slope was reclassed on a scale 1 to 5 with the flatter being more vulnerable assigned scale 5. Landuse was reclassed with Bareland having scale 5 (more vulnerable), water with scale 4, built-up with scale 3, vegetation with scale 2 and plantation with scale 1. In flow accumulation operations, output cells with a high flow accumulation are areas of concentrated flow and were used to create stream channels/network. This operation usually sets the value range of the output map from 0 to 999999999 and sets the step size to 1. The range produced from the map would be divided by the number of reclassifications so as to have equal interval to cater for the reclassification scale of 1-5.

Three scenarios were used in this research to predict future outcome of flood vulnerability in the study area. These scenarios were differed by the percentage influence of vulnerability factors of elevation, slope, landuse, flow accumulation and rainfall intensity. In scenario one, rainfall was taken to be a constant factor while the influence of other factors was varied to create the vulnerability map. This is because considering the size of the study area rainfall intensity is not likely to vary much. In the second scenario, same percentage influence of 25% was used for all factors to see what the result would be like if all factors contribute equally to flood vulnerability in the area. Percentage influence of flow accumulation and rainfall intensity was increased to 30% apiece in the third scenario while slope was assigned 20%, landuse 15% and elevation was assigned 15%. The three factors of rainfall intensity, flow accumulation and slope have the tendency of contributing greatly to flood in an area. Assigning higher percentage influence to these factors is to see what the outcome would be.

3. RESULTS AND DISCUSSION

3.1. Factors of Flood Vulnerability in Ado-Ekiti

Based on the reviewed works and onsite assessment, the following factors were identified as factors of flood vulnerability in the study area; Land use and land cover (which includes vegetation, water bodies, built-up areas and bare lands), slope, elevation, flow direction of water runoff, encroachment of river banks and rainfall intensity. Figure 3 shows the result of land use land cover of the study area with five classes resulting from the factors that can make a place within the study area vulnerable to flooding. Table 3 shows that vegetation covers most part of the study area with 52.15% while water covers just 1.11% of the entire area. There is 20.13% of land use cover of built-up area and a plantation cover of 15.27% of the study area. The large vegetation cover should have been an advantage for checking flooding in the study area but these are outside the built-up areas as shown in Figure 1. Bare land accounted for 11.33% of the land use land cover and this is another exposure to the risk of flooding in the study area.

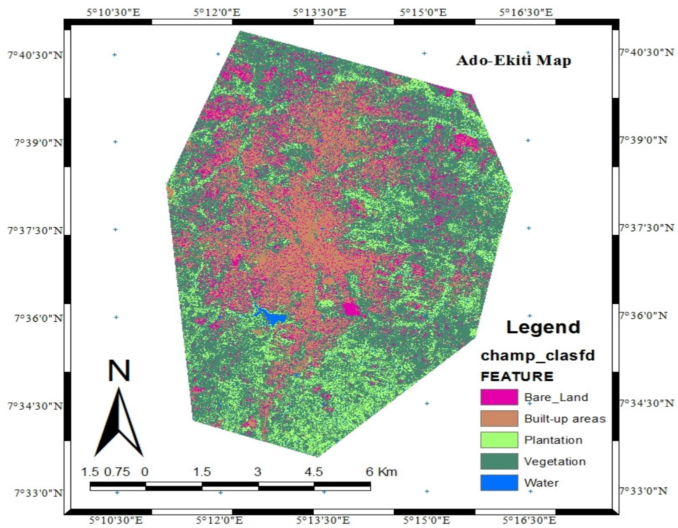

Figure 3: Landuse landcover map of study area

Table 2: Classification table

Features	Area (Sq km)	% Cover
Vegetation	47.048	52.15
Water	1	1.11
Built-up areas	18.164	20.13
Bare_Land	10.225	11.33
Plantation	13.775	15.27
Total	90.212	100.00

3.2. Spatial Analysis using Multi Criteria Approach

Slope analysis results show that areas within Fayose Estate, Adebayo, Odo-Aremu, GRA, Omisanjana, Ekute, Olujoda, Ajebamidele, Bawa, Bisi Egbeyemi Crescent and Moferere have lower slope degrees (Figure 4), which is an indication that these areas mentioned has higher probability of receiving much water in case of runoff thereby being vulnerable to flooding. An area before Ekute quarters with slope degree value 0 actually represents the location of Ajilosun dam which receives most waters flowing in that area and its immediate environs.

The DEM of the study area ranges from 361 to 661 meters above sea level. Low elevations are found in east and patches of high points are scattered across the northwest, southwest and southeast of the town (Figure 5). From the map, it can be concluded that the study area is dominated by height range 429-464m above sea level.

Results of flow accumulation analysis shows areas of no accumulation with 0 value and other areas with accumulation values higher than 0 represented in blues colour which form line features representing stream channels. Figure 6 also showed that areas like Moferere, Omisanjana, Ureje, Igirigiri and Agric Olope are nearer to high accumulation points, therefore observed to be vulnerable to flooding.

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The rainfall intensity at five levels of very high, high, moderate, low and very low are depicted in the Figure 7. The blue colored areas show the very low rainfall zone while the cream color areas show the very high rainfall zone.

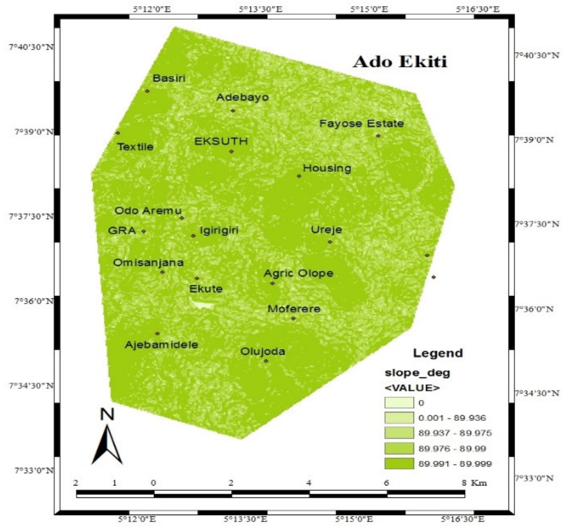

Figure 4: Slope map of the study area

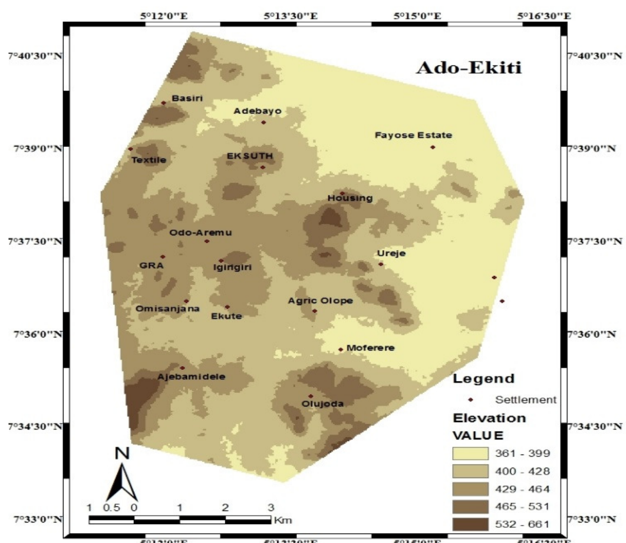

Figure 5: Elevation map of study area

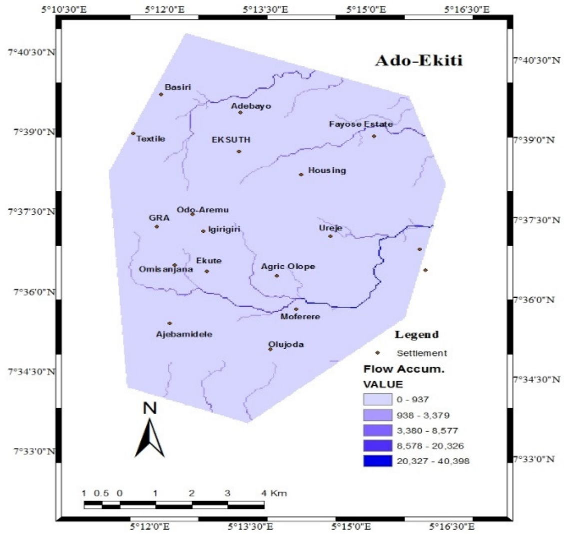

Figure 6: Flow accumulation of study area

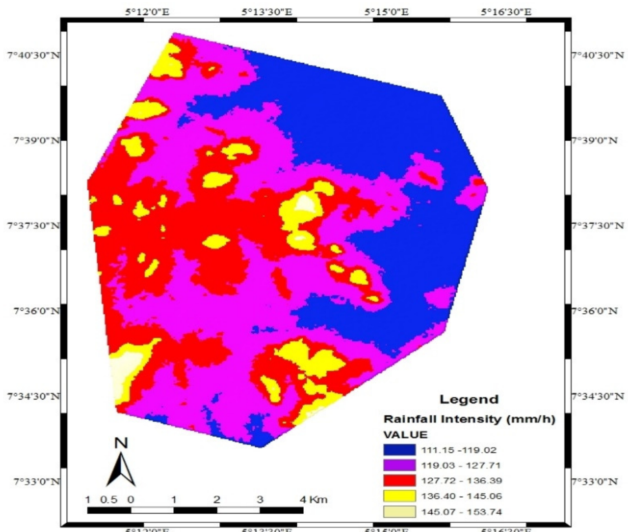

Figure 7: Rainfall intensity map

3.3. Mapping Areas Vulnerable to Flooding at Different Scenario

Results of scenario one (Table 3) shows that 0.18% of the entire study area falls under very high vulnerability and going by the vulnerability map (Figure 8), such areas as EKSUTH, Textile and Igirigiri are very highly vulnerable to flooding. The areas with high vulnerability accounts for about 31.49% of the study area and communities like GRA, Odo-Aremu, Ekute, Omisanjana, Ajebamidele, Ureje, etc falls in this category. Only Moferere and Adebayo areas falls within the 54.65% areas with medium vulnerability in the study area.

In scenario two, 0.29% of the entire study area falls under very high vulnerability which includes EKSUTH, Textile and Igirigiri. The areas with high vulnerability accounts for about 20.09% of the study area and communities like GRA, Odo-Aremu, Ekute, Omisanjana, Ajebamidele, Ureje, etc falls in this category while Moferere and Adebayo areas falls in the 59.22% areas with medium vulnerability in the study area.

Scenario three in Table 3 also shows that 0.29% of the entire study area falls under very high vulnerability and this include such areas as EKSUTH, Textile and Igirigiri. The areas with high vulnerability accounts for about 20.02% of the study area and communities like GRA, Odo-Aremu, Ekute, Omisanjana, Ajebamidele, Ureje, etc falls in this category. Moferere and Adebayo areas falls within the 59.26% areas with medium vulnerability in the study area.

Table 3: Area coverage of the flood vulnerability in three scenarios

Vulnerability	Scenarios one		Scenarios two		Scenarios three	
	Area in km^2	%	Area in km^2	%	Area in km^2	%
No Vulnerability	0.09	0.10	0.12	0.13	0.12	0.13
Low vulnerability	13.51	13.58	19.37	20.27	19.40	20.30
Medium vulnerability	51.41	54.65	56.57	59.22	56.62	59.26
High vulnerability	29.75	31.49	19.20	20.09	19.12	20.02
Very High vulnerability	0.17	0.18	0.28	0.29	0.27	0.29
Total	95.53	100.00	95.53	100.00	95.53	100.00

Comparing the scenarios, it was observed that the results of scenarios two and three are closer in terms of their area coverage which is highly different from the results of scenario one. When the factors were altered, it showed that area coverage of high vulnerability in scenario two (20.09%) and three (20.02%) reduced from scenario one with 31.49% coverage and these areas includes GRA, Odo Aremu, Ekute, Omisanjana, Ureje, etc.

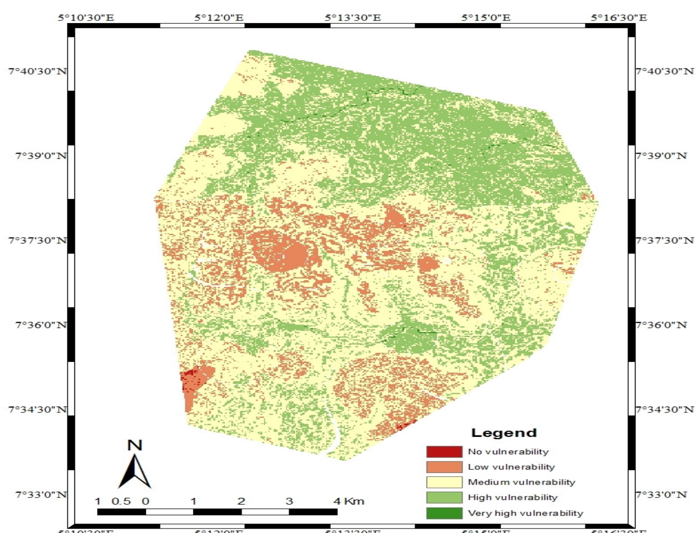

Figure 8: Vulnerability map (Scenario one)

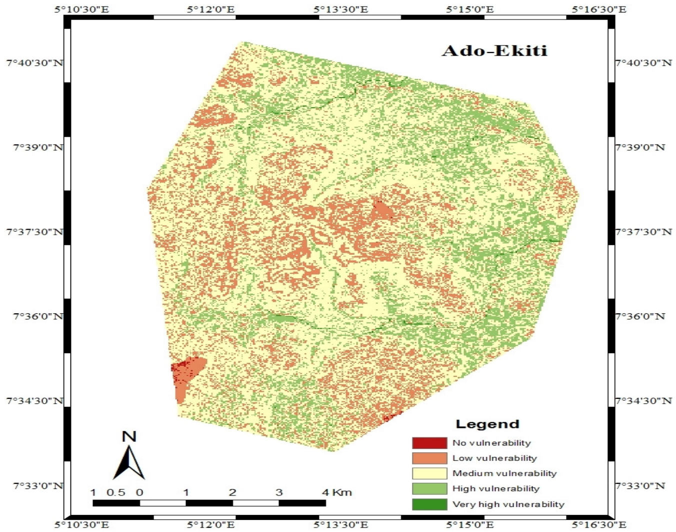

Figure 9: Vulnerability map (Scenario two)

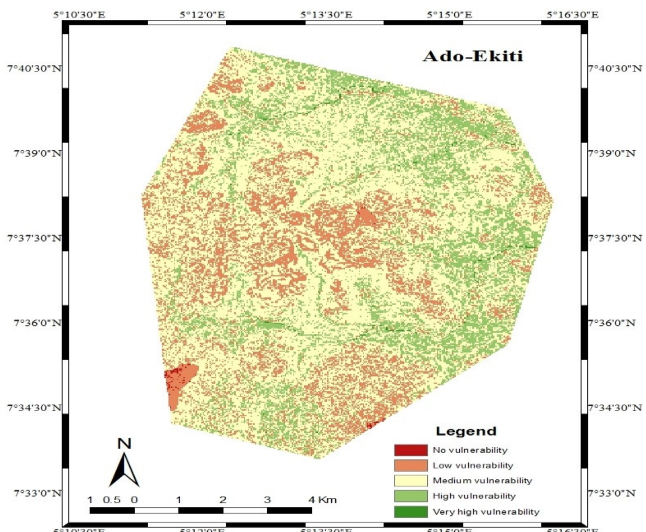

Figure 10: Vulnerability map (Scenario three)

4. CONCLUSION

The study has successfully identified the factors responsible for flooding in the area and their distributions. The study also generated a flood vulnerability map for Ado-Ekiti in three different scenarios according to different rainfall intensities. A comparison of the results showed that area coverage of high vulnerability in scenario two (20.09%) and three (20.02%) reduced from scenario one which has 31.49% coverage and these areas includes GRA, Odo Aremu, Ekute, Omisanjana, Ureje, etc. It can be concluded that more than 90% of all communities in Ado-Ekiti are vulnerable to flooding though at different levels. Environmental researchers should consider use of scenario in their studies to see how current and alternative development path might affect the future. This will go a long way in assisting policy formulations geared towards preventing the occurrence of natural hazards or reducing their effects.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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