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Flood Vulnerability Evaluation in Ado-Ekiti Using Remote Sensing and GIS

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ABSTRACT
One of the most significant natural disasters in Ekiti, is flooding. In Ado-Ekiti, for instance, as a rapid urbanizing context located in L.G.A has been affected by several flood events during last decade. Severe rainfall, natural situation, new unplanned developments and insufficient drainage systems made the situation more considerable. This study seeks to address the crucial variables which contribute to the risk of flooding based on the characteristics of the region and develop a GIS-aided urban flood susceptibility map. The methodology emphasizes on uncertainty and multi-criteria which contribute to the risk of flood and increase the risk. As such, the Fuzzy logic, Multi-criteria ranking and Weighted Linear Combination (WLC) methods in Geographic Information System (GIS) were used to achieve the objectives. Distances from main stream, river and discharge channels, as well as other variables such as elevation, slope and land use are recognized as effective variables within the region. Final susceptibility map indicates that around 76.530km out of 397.232km within the region is under the high level of flooding risk.
Keywords: Flood mapping, Vulnerability, Risk, Rainfall, Remote Sensing, GIS

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I. Introduction

According to Suleiman *et al*, floods are major disasters affecting many countries of the world annually, especially in most flood plain areas. Floods do not only damage properties and endanger the lives of human and animals but also produce other secondary effects like outbreak of diseases such as cholera and malaria as well. Flooding is commonly caused by heavy downpours of rains on flat ground, reservoir failure, volcano, melting of snow and or glaciers etc. Flood risk is not just based on history; but on a number of factors: rainfall, river flow and tidal-surge data, topography, flood control measures, and changes due to construction of building and development on flood plain areas.

Flooding is caused by several factors and is invariably preceded by heavy rainfall. The other causes of flooding are moderate to severe winds over water, unusual high tides, tsunamis due to undersea earthquakes, breaks or failures of dams, levees, retention ponds or lakes, or other infrastructure that retains surface water. Flooding can be aggravated by impervious surfaces or by other natural and man-made hazards which destroy soil, vegetation that can absorb rainfall (Suleiman *et al)*.

Flood disaster management like other disasters management can be grouped into phases; the preparedness phase where activities such as prediction and risk zone identification or vulnerable mapping are taken up long before the event occurs, the prevention phase where activities such as forecasting, early warning, monitoring and preparation of contingency plans are made before or during the event, and the response and mitigation phase where activities are undertaken after the disaster and this includes damage assessment and relief management (Van Western *et al.*, 2000).

Mitigation of flood disaster can be successful only when detailed knowledge is obtained on the expected frequency, character, and magnitude of events in an area as well as the vulnerability of the people, buildings, infrastructures and economic activities in a potential dangerous area (Van Western and Hosfstee, 2000). However, Ifatimehin*et al.* (2009), Ifatimehin and Ufuah (2006) reported that this detailed knowledge is always lacking in most urban centers of the developing world especially Nigeria.

The recurrent flood events in the study area thus necessitated the need for proper monitoring and evaluation of the causes of flood and solutions to the problems. The aim of this study is to apply

Geospatial Techniques using Shuttle Radar Topography Mission (SRTM) satellite data in mapping flood vulnerable areas of Ado Local Government Area for disaster management.

II. Study Area

Ado-Ekiti, the study area is located within the North Western part of the Benin-Owena River Basin development Area. The population of the region was projected as 536,000 (www.populationstat.com). The city lies between Latitude 7^{O} 34’ and 7^{O} 44’ North of the Equator and Longitude 5^{O} 11’ and 5^{O} 18’ east of the Greenwich Meridian. It has a number of Satellite towns around it. Ado-Ekiti enjoy the privilege of been a nodal town and located at the centre of the state; hence roads that leads to other parts of the state converge in the city.

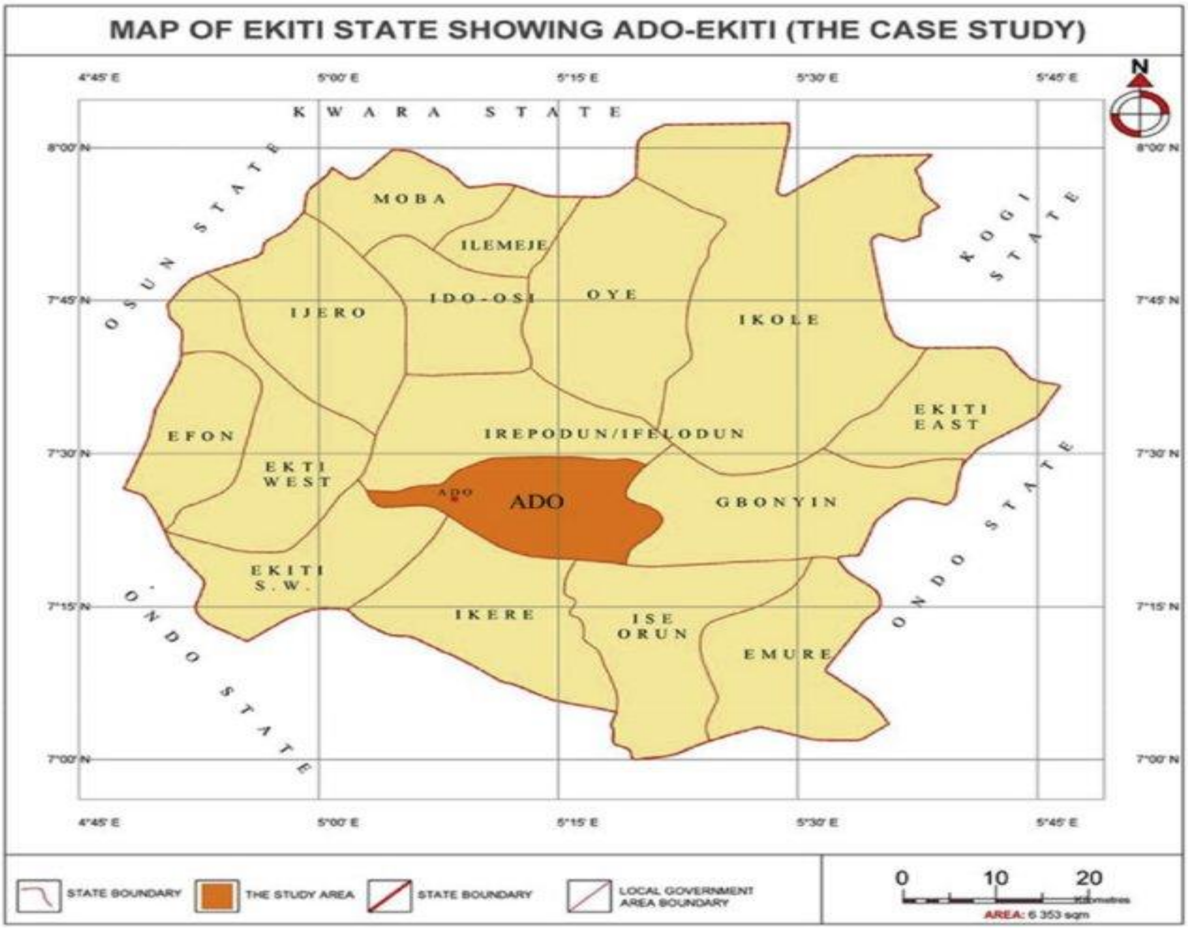

Fig. 1: Map of Ekiti state showing the study area

The change in the economic and political status of the city has brought a corresponding increase in the number of its inhabitants. The city had a projected population of 274,205 in the year 1995 while that of 2030 is put at 1.11 million given the current growth rate of 3.33% per annum out of which 82 percent are expected to live in urban.

III. Materials and Methods

Both primary and secondary data were utilized for this study.

Primary data

The primary data included Ground Control Point (GCP) acquired using GPS**.** These were acquired strictly by ground survey method. It involved direct field observation method and measurement to obtain the coordinates of different locations in the study area by the use of the GARMIN III handheld GPS (Global Positioning System) and Photographic camera was used to take pictures.

Secondary data

This involved the satellite images; the satellite imagery used for this project includes: Shuttle Radar Topography Mission (SRTM) Digital elevation model (DEM) data, annual rainfall data for 2020 of the area gotten from Tropical Rainfall Measuring Mission (TRMM), Landsat8 for 2021, Soil vector map from Nigerian Geological Survey and downloading of materials from the internet.

Table 1: Data used for the study and their sources

S/n	Type	Format	Scale/Resolution	Year	Source
1	SRTM	Digital	30m	2023	United States Geological Survey (USGS)
2	Landsat8	Digital	30m	2021	United States Geological Survey (USGS)
3	Rainfall	Digital	30m/ Annual rainfall data	2020	Tropical Rainfall Measuring Mission (TRMM)
4	Soil Map	Digital	Vector file/ no resolution	Rectified 2023	Nigerian Geological Survey
5	Administrative map	Analog	1:10.000	-	Office of the Surveyor General of the Federation.

Image Processing

The layer of data extracted from the soil map, satellite image and meteorological data from table 1 above were integrated in a GIS environment and further subjected to Multi-Criteria Analysis (MCA) using the Weighted Linear Combination (WLC) approach. Spatial analysis was carried out on the derived result using the Critical Index (CRI) value. Finally, areas that are vulnerable to flooding were mapped out.

Flood Risk Criteria Analysis

1. **Elevation:** The elevations of the study area mapped out from obtained SRTM 30M DEM data in ARCGIS 10.4.1 environment. The Digital Elevation Model of the study area was used to extract slope and drainage as input in the analysis.
2. **Slope:** The slope of the study area was gotten from the Digital Elevation Model. The digital elevation model which shows variation in elevation was used to generate the slope. This was generated by using spatial analysis tool in arc tool box in the arc map software. The slope was therefore from the surface tool in the spatial analyst tool in the arc tool box. The slope hereby shows the relief of the area at various elevations.
3. **Rainfall:** The rainfall data which was gotten at various stations was recorded in Excel showing daily rainfall for 2023. The average of the rainfall was found and it was imported into the ArcMap software. The interpolation tool in the arc-tool box was used for the interpolation by using the IDW method in the interpolation tool. The interpolation shows different regions having different rainfall.
4. **Soil Map:** Soil map was produced from geological layers. Geological layers decompose to form soil. The soil map of the area shows the variability of soil types of the area.
5. **Landuse:** The land cover for the study area was produced from Landsat Operational Land Imager (OLI) popularly known as Landsat 8, which was downloaded from United States Geological Survey (USGS) website. The landsat data was acquired in 2023. The land use was done in the ARCGIS 10.4.1 environment.

Ranking of Flood Risk Criteria

All criteria (DEM, Drainage network, Precipitation, Slope, Soil type, and Land cover) were reclassified, and a linear function was used to assign preference value to different classes of all criteria. The unified preference value ranges from 1 to 4, which is equivalent to 25 to 100. 1(25) is the minimum preference value and 4(100) signifies high preference value. The maximum preference value (4) is ranked high preference for the flood vulnerable.

Multi-Criteria Decision Making

The ranking and prioritization process is the main purpose of AHP based multi-criteria decision making. The quality of priority-setting directly influences the effectiveness of available resources which are, in most cases, the primary judgment of the decision maker.

By this technique, a weight value ranges from 1 to 4 was assigned to each factor by the experts to reflect their relative significance. Using the Weighted Linear Combination (WLC) method, all the map layers (the factors) were overlaid in the final GIS spatial analysis for flood vulnerability zones simulation.

The WLC technique was carried out using ArcGIS software. This permits the evaluation criterion map layers to be overlaid in order to obtain the composite map layer which is output. Therefore, the output of this WLC method gave a map which simulated the most potential flood susceptible zones of flood vulnerability mapping of Ado-Ekiti.

IV. Results and Discussion

Six (6) criteria, produced from the acquired datasets were considered as the main factors for this study which are; DEM, drainage network, precipitation amount (rainfall), topographic condition (slope), soil type, and land cover.

Suitability Evaluation

All criteria (DEM, Drainage network, Precipitation, Slope, Soil type, and Land cover) were reclassified, and a linear function was used to assign preference value to different classes of all criteria. The unified preference value ranges from 1 to 4, which is equivalent to 25 to 100. 1(25) is the minimum preference value and 4(100) signifies high preference value. The maximum preference value (4) is ranked high preference for the flood vulnerable.

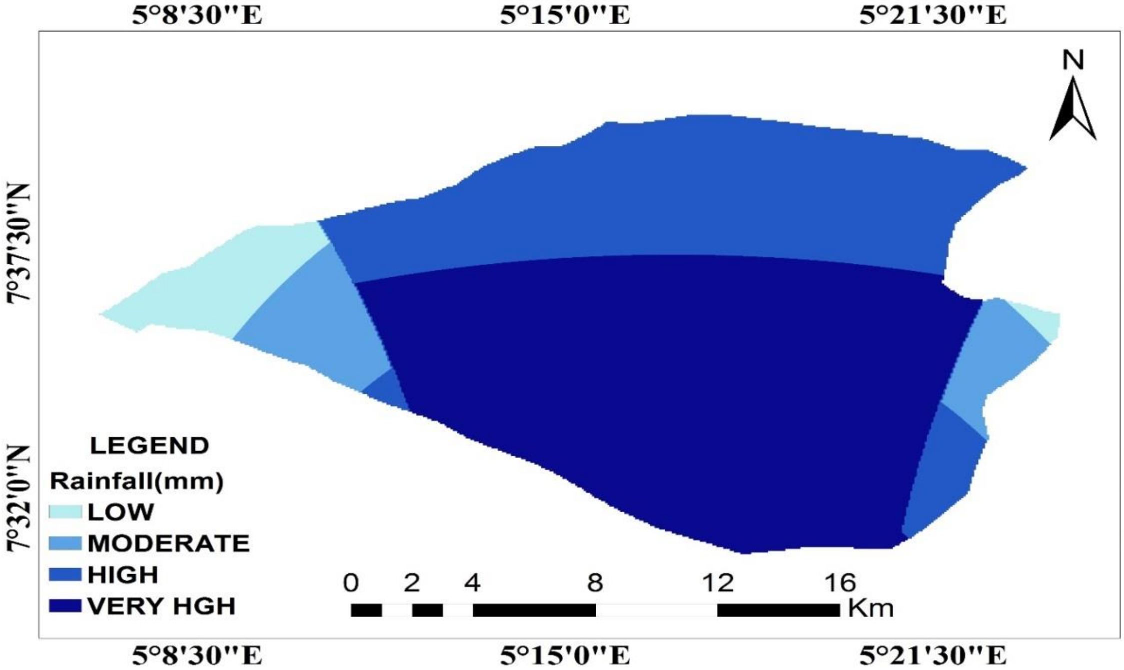

Figure 2: Reclassified rainfall distribution map

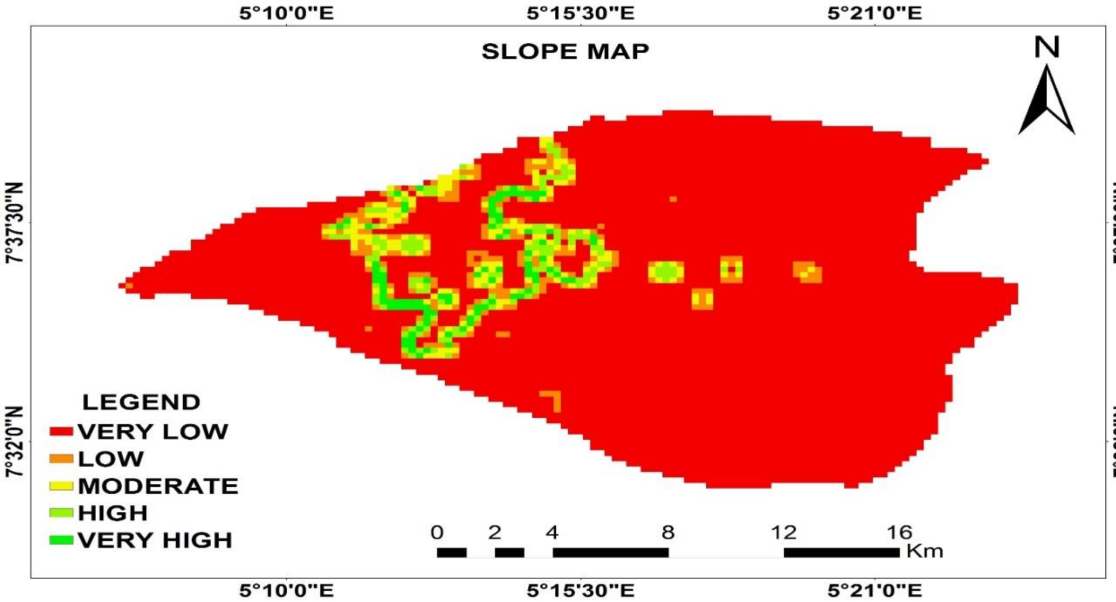

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Figure 3: Reclassified degree of slope

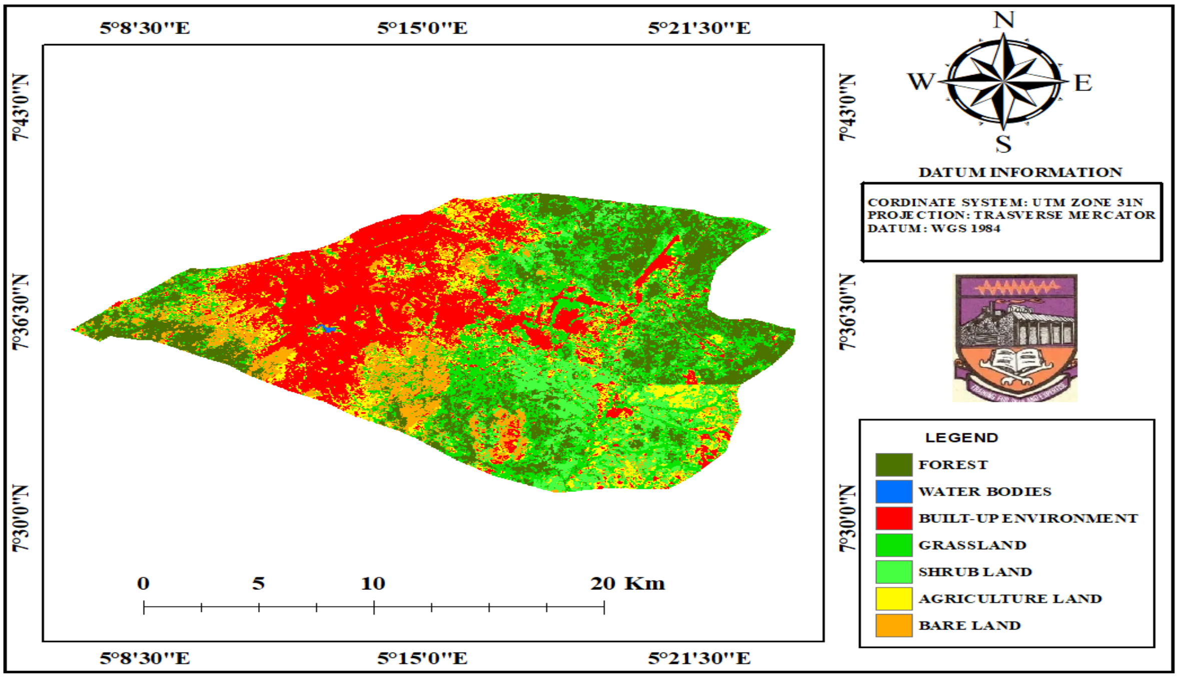

Figure 4: Reclassified land cover

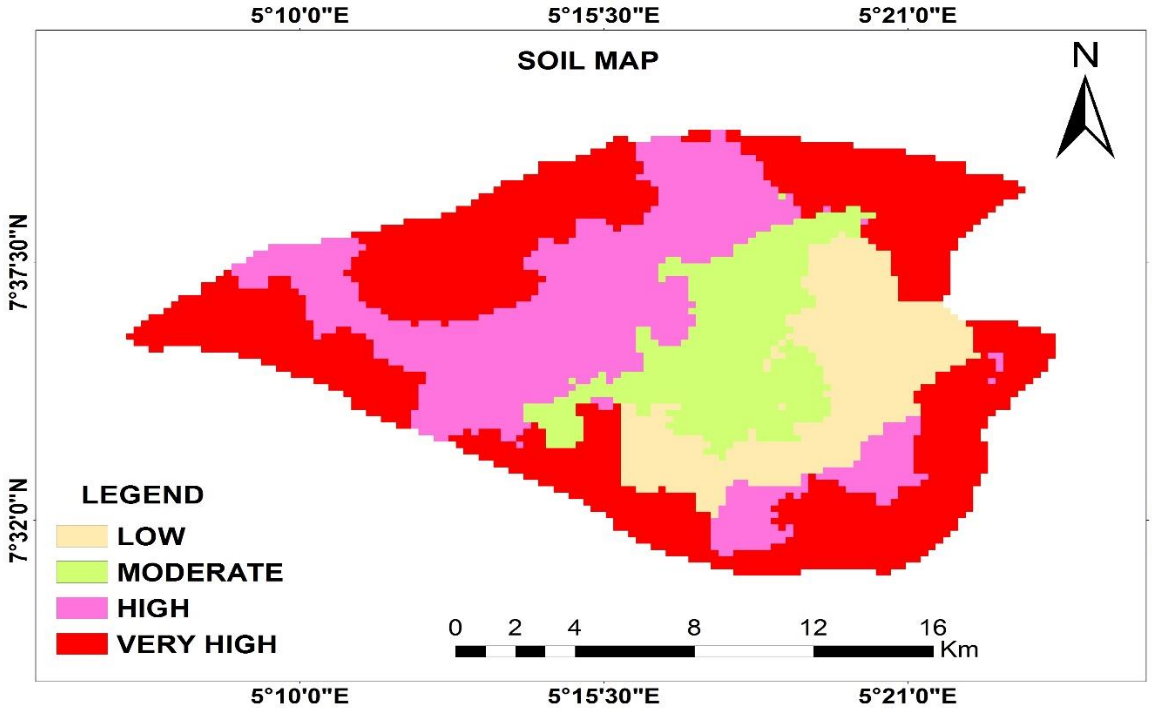

Figure 5: Reclassified soil type classes

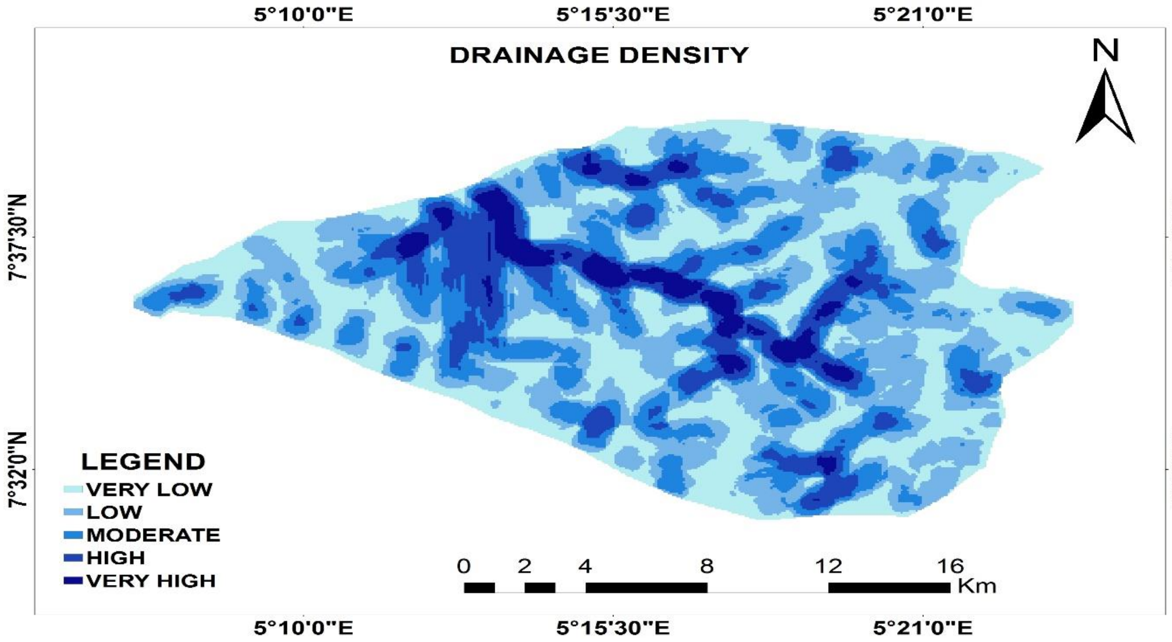

Figure 6: Reclassified drainage order

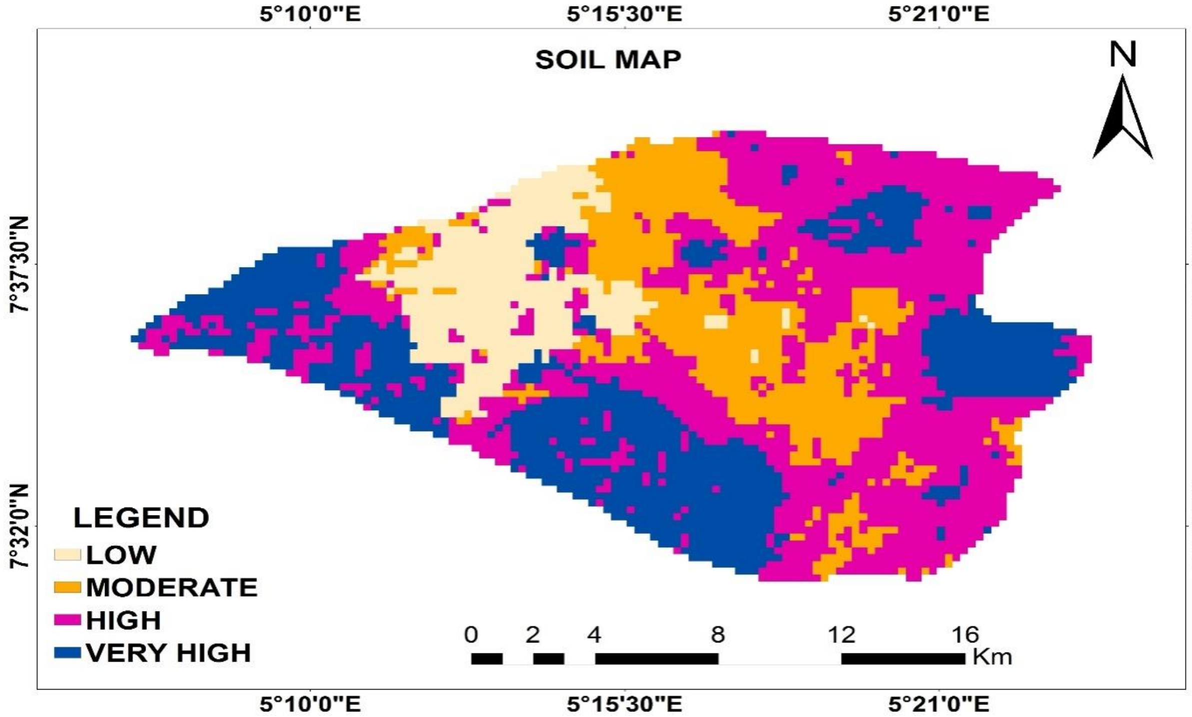

Fig 7: Reclassified Digital Elevation Model

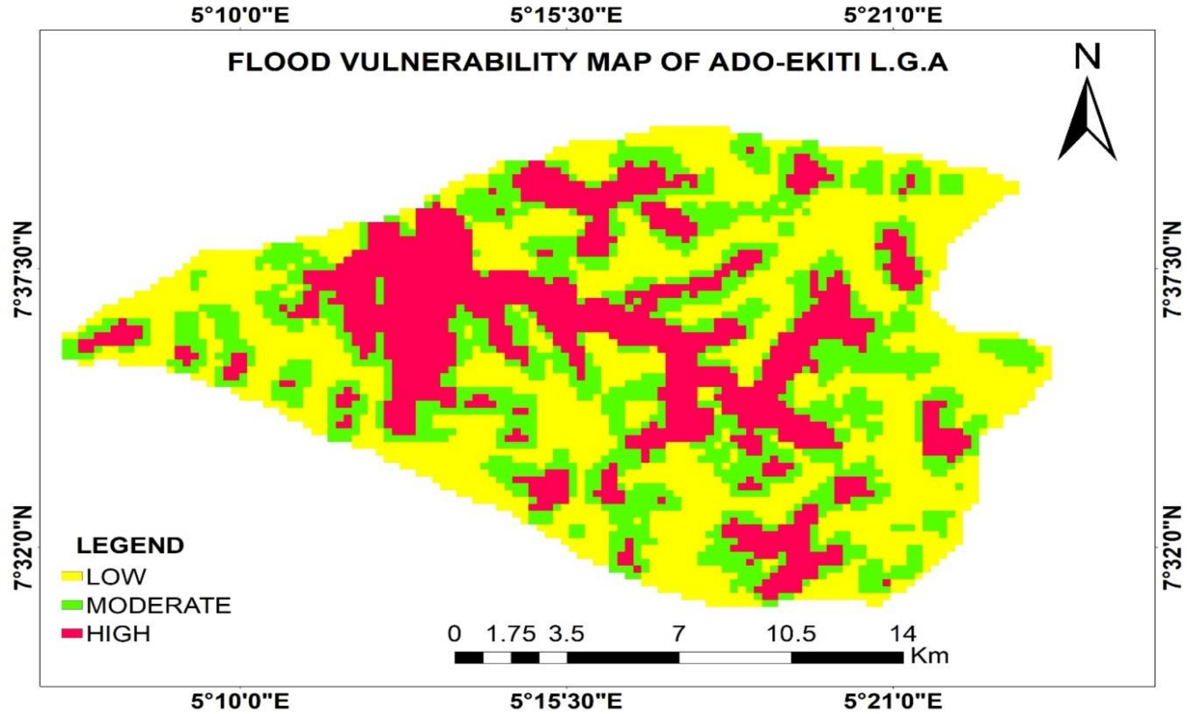

Figure 8: flood vulnerability map of Ado L.G.A

Table 2 shows the flood vulnerable areas of Ado local government. The high vulnerable area has the lowest value in km^2. The high vulnerable areas covered 76.530km^2 (19.27**%**), the moderate vulnerable areas covered 36.142km^2 (9.1**%**) and the low vulnerable areas covered 284.560km^2 (71.63**%**). This shows that part of the study area is prone to flood. Areas with settlement with improper planning and also house built around the bank of the river are likely to experience flood.

Table 2: Flood Vulnerability Areas

CATEGORY	AREA (km^2)	AREA (%)
HIGH	76.530	**19.27**
MODERATE	36.142	**9.1**
LOW	284.560	**71.63**
TOTAL	397.232	100.00

(Source: Author, 2023)

V. Conclusion and recommendations

The flood vulnerability map generated shows the various degrees of flood risk and that such information can be useful in safeguarding the lives and properties of inhabitant living in Ado L.G.A and to reduce high risk occurrences of flood disaster within the area. The result shows that the high vulnerable areas covered 76.530 km^2 (19**%**), the moderate vulnerable areas covered 36.142km^2 (9**%**) and low vulnerable areas 284.560km^2 (72**%**) of the study area. From the study the following recommendations were made to tackle the problem of flood and for further studies:

- Developmental projects on flood prone areas should be critically analyzed based on the effective factor causing flood in order to mitigate the hazard.
- Areas that have high flood vulnerability should be properly channeled.
- The map should be used as a tool by the town planning activities not to give approval to building in areas prone to flood.
- This map should be used as a tool in environmental impact assessment study of Ado Ekiti.
- Ministry of environment should enforce the prevention of dumping of refuse along/in river courses.
- Vegetation should be planted to act as flood breaks, reducing the velocity of flow.

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