DETECTING OF FLOOD RISK AREAS USING GIS AND ANALYTICAL HIERARCHY PROCESS (AHP) APPROACH

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Abstract

Nigeria suffers floods as one of her major destructive natural disasters due to several reasons such as climate change effects, land use, elevation change, etc. Flood hazard is a product of both natural and human activity, necessitating a swift and improved understanding of its geographic scope. The purpose of this study is to locate and map flood-prone sites in the Yewa (Egbado) South Area. Four (4) criteria—land use, DEM (Digital Elevation Model), flood direction, and slope—have been chosen for this analysis of flood-prone locations using spatial analysis in the geographical information system (GIS) environment. Weight overlay comparative map of these criteria was done using the assigned weight and ranking based on the influence on the flood of the study area from the Analytical Hierarchy Process (AHP) to produce a flood risk map of the area, showing Ibese and part of Ilaro to fall within low flood risk zone of 2%, 81% of medium flood risk zone covers a larger percentage of the area and the high flood 17%.

Keywords: flood risk, AHP, weight overlay & GIS.

Introduction

According to the Nigerian National Emergency Management Agency (NEMA), 30 out of 36 states in Nigeria were impacted by floods in 2012 alone, displacing nearly 1.3 million people and claiming 431 lives. Therefore, it is crucial to assess how this disaster has affected society.

Ouma & Tateishi, (2014) explained flood risk consists of hazard and vulnerability. They described Hazards as threatening occurrences or an event with potentially damaging effects in a place at a given time. When an event is described to be hazardous, then damage must have occurred and the risk element is what determines the level of damage. These elements are the people, infrastructure and economic activities, etc. On the other hand, vulnerability is the most important element of risk since it decides whether or not exposure to a hazard represents a danger that could lead to a catastrophe. Therefore, it is a necessity to carry out a such study in Yewa (Egbado) South Area most especially adopting the Analytical Hierarchy Process (AHP) approach for the detection of flood risk in the said area. (Barroca et al., 2006).

One of the most frequent natural and man-made calamities in the world today is flooding. Heavy rains and coastal storms are the natural causes, while burst water main pipes, inadequate drainage systems, land use patterns, failed dams, and illegal trash disposal are the human reasons. Due to human migration into floodplain areas to secure land of their own or inhabit affordable dwellings, the rate and intensity of natural catastrophes have increased with the world's population growth and urbanization (Oladejo & Taiwo, 2018).

Ouma & Tateishi, (2014) in a study of Eldoret Municipality in Kenya, a GIS and AHP approach was used to integrate the flooding causative factors such as rainfall distribution, elevation and slope, drainage network and density, land-use/land cover and soil type to produce a flood risk vulnerability map that shows the aforementioned. It was discovered that small streams in urban areas can rise quickly after heavy rain due to higher generated runoff and less concentration time. Many states in Nigeria are subject to this natural disaster, Lagos state for instance has this disaster flooding as its major plague as shown in fig 1A, and it has been continually linked to the urban developmental rate (Dorcas & Wendy, 2021). The development of land within the flood-prone zone has affected the coastline geometry in Lagos. Dorcas & Wendy, (2021) agrees that the need to monitor urban growth rate and the pattern is a primary assignment for planners and policymakers. This assessment is of a high need for continuous planning and updating, additionally, the lack of sufficient and reliable data from “standard” hydrology and climatology of Nigeria justifies this need.



Fig 1: A-Flood in Lekki phase 1 area of Lagos state and B- Flood in Ifo area of Ogun state. Source: phone capture 2022.

When determining flood risk GIS will be a useful tool that will enable people to view, comprehend, query, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps or imagery, as the case may be. Additionally, many research have substantiate the use of spatial analysis in the GIS environment to estimate flood risk zones. The flood-prone locations can be interpreted into any information system framework, this stands achievable as the availability of remotely sensed data continues to make the GIS tools relevant to earth's relational problems (Alausa & Adaradohun, 2018).

GIS has become a powerful information integration system, which can be used to map the evaluated results gotten from AHP analysis. The Analytic Hierarchy Process (AHP) is a full-bodied and elastic tool for dealing with multifaceted decision problems, this method divides a complex system into a hierarchical system of elements which usually include purposes, assessment, standards, and alternatives. It also allows for multiple decisions using criteria and prioritization.

in addition, the Analytic Hierarchy Process (AHP) has become a useful tool for qualitative and quantitative assessment to attain a meaningful decision-making process. (Lyu et al., 2018).



Fig 2: Flood in Ilaro, Ogun state. Source: Phone capture 2022.



Fig 3: A &B- Flood in Oju ore road, Sango Ogun state. Source: Phone capture 2022

A flood hazard map of Egbado south in Ogun state was produced showing the flood risk areas, this is necessitated due to the flood event that has caused a lot of major damages and destruction to properties and lives, choiceless displacements and abandonment of livelihood and lifetime investments respectively severally in any major rainfall as shown in fig 2. A map is a crucial tool for determining how susceptible flood-prone areas are. To estimate flood risk zones, spatial analysis in a GIS context has been used. Four relevant physical criteria, namely slope, elevation, land use, and flow direction, have been chosen. When using the Analytical Hierarchy Process, the relative relevance of physical factors has been examined in a pairwise matrix to get the weight values (AHP).

2.0 STUDY AREA

The study area Egbado South is a local government area (LGA) in Ogun state. It was formally called Yewa South Local Government Area, Ilaro town stands as the headquarters of this LGA, the following are the major towns within the LGA Ibese, Ajilete, part of owode, Itoro, Iwoye, Idogo, and Ilaro. Egbado south LGA was established in the year 1976, the LGA can be found at a longitude of 6°47'51.47" N and a latitude of 2°57'41.18" E as shown in fig4 below.

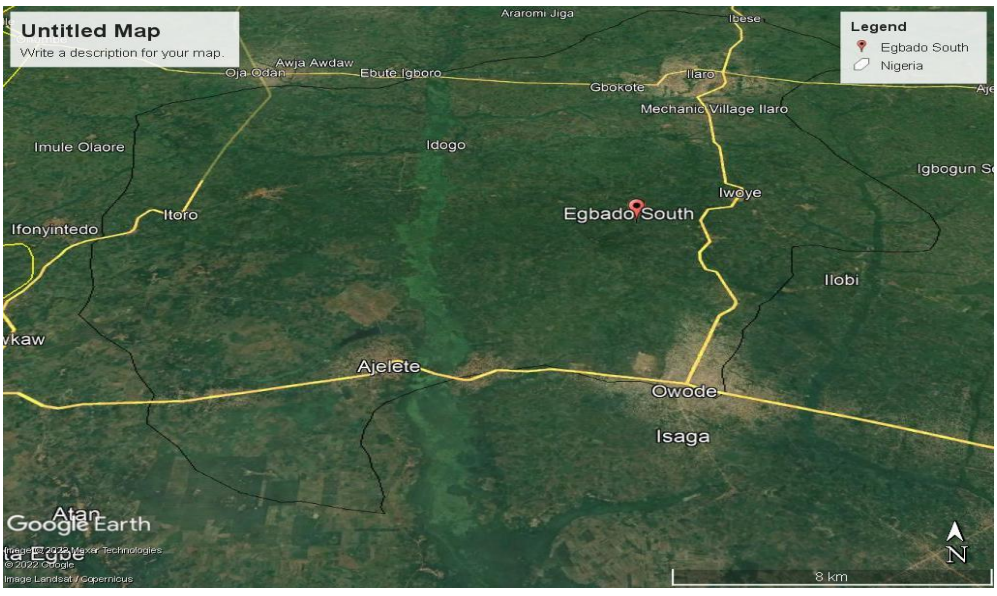


Fig 4: Egbado south local government area (source: Google earth image 2022)

3.0 METHODOLOGY

Going through records AHP, have been a tool in use, according to Saaty in 1980 he proposed to adopt AHP for analyzing problems with several factors considered. In this study, Pair-wise Comparison Method was engaged for the development of the flood risk map.

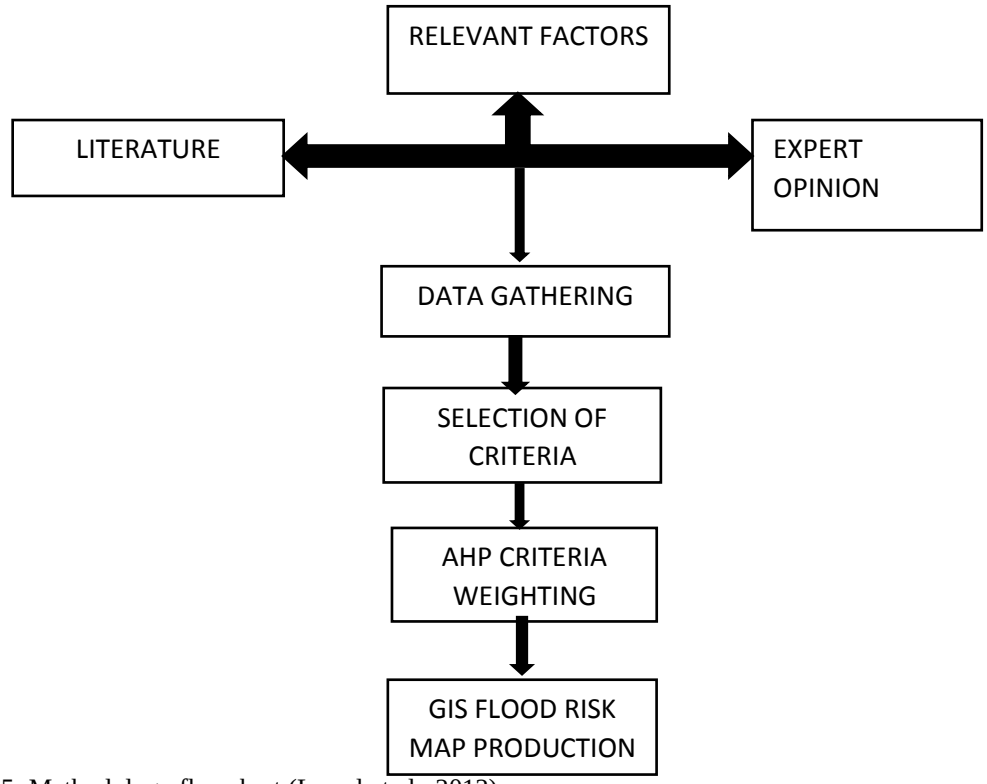


Fig 5: Methodology flowchart (Lawal et al., 2012)

Data Gathered for Criteria Selection

In criterion selection, the factors with spatial data of better accuracy are preferred to aid a reliable result (Lawal et al., 2012; Malczewski, 1996). The factors relevant to floods in the study area based on literature and expert opinion are selected for the pairwise comparison process to generate a flood risk map. The following factors are considered in table 1 below, with their source of data stated.

Table 1: Criteria and Data source

S/N	CRITERIA	SOURCE
1	Land Use/Land Cover	Sentinel-2 10m (https://www.arcgis.com/home/webscene/viewer.html?layers=d3da5dd386d140cf93fc9ecbf8da5e31)
2	Digital elevation Model (DEM)	SRTM https://dwtkns.com/srtm30m/
3.	Slope	Generated from the DEM in the ArcGIS environment
4.	Flow Direction	Generated from the DEM in the ArcGIS environment
5.	Egbado south boundary shape file	Google Earth https://earth.google.com/web/

Decision Matrix

The 1–9 scale of factors importance (Saaty 1980).

Strength of importance explanation

1 Equal significance

3 Medium significance

5 Strong

7 Very strong significance

9 Maximum significance

2, 4, 6, and 8 Intermediate between two adjacent values

The business performance management Singapore software was used to perform the evaluation, ranking each factor among others to generate a weight for each factor. AHP steps were followed, and the problem was modeled to determine the selection of the determinant factors, the determination of priorities among the selected factors, the derivation of overall relative weights of the factors, and the verification of the consistency ratio. Table 2 below are the resulting matrix and table 3 shows the weight reference derived from the online software. The resulting weights are based on the principal eigenvector of the decision matrix:

Table 2: Decision matrix

	COMPARISON MATRIX			
	LAND USE	ELEVATION (DEM)	SLOPE	FLOW DIRECTION
LAND USE	1	1	3	5
ELEVATION (DEM)	1	1	3	3
SLOPE	0.33	0.33	1	3
FLOW DIRECTION	0.2	0.33	0.33	1

AHP weight Priorities

These are the resulting weights for the criteria based on your pairwise comparisons for Egbado south:

Table 3: **weight Priorities**

Category	**Criteria**	**Priority**	**Rank**	**(+)**	**(-)**
1	LULC	39.90%	1	4.80%	4.80%
2	DEM	36.00%	2	9.50%	9.50%
3	SLOPE	15.90%	3	5.40%	5.40%
4	FLOW DIRECTION	8.10%	4	2.70%	2.70%

Number of comparisons = 6

Consistency Ratio CR = 4.2% (less than 10%) is acceptable to perform the weighted overlay calculations to incorporate the weighted parameters for the flood risk mapping (Allafta & Opp, 2021)

4.0 RESULT AND DISCUSSION

The calculated priority weights in table 3 were used in ArcGIS 10.6 software for weighted overlay analysis using the weighted overlay tool inputting the flood factors to produce a flood risk map. Fig5-fig 8 below shows the series o map produced and overlayed to generate fig 10.

LAND USE LAND COVER MAP

The land use land cover map was classified into four different classes, water, vegetation, built-up area, and bare ground. The map showed that Ilaro is the most developed area in the LGA and much of the water land covered by vegetation is classified along with vegetation area. From fig5 below the vegetation covers the largest percentage of the Egbado south local government area, showing that Egbado south residents major in farming activities.

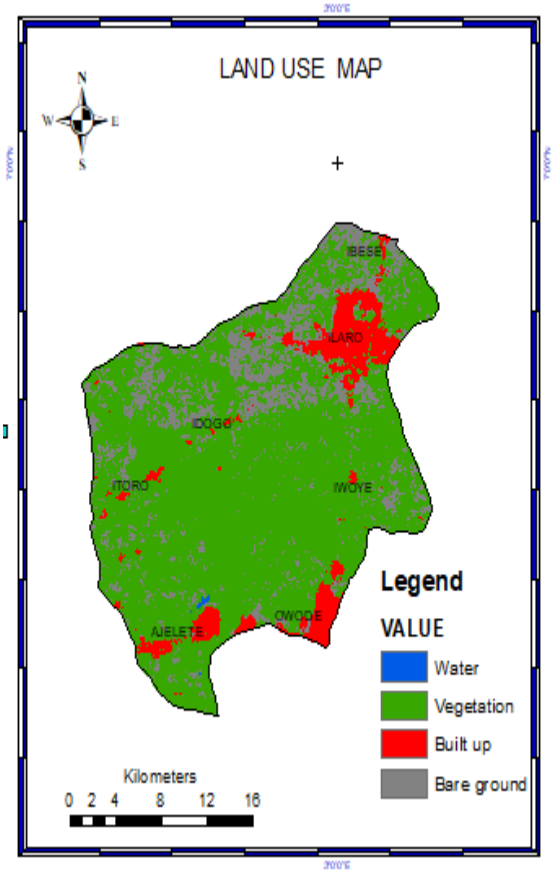


Fig 5: Land use land cover map of Egbado south

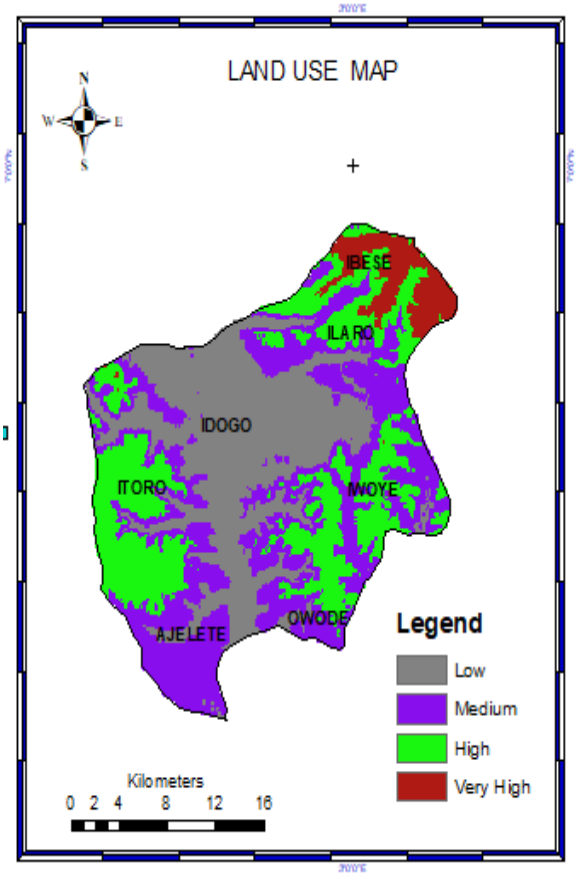


Fig 6: Elevation map of Egbado south

DIGITAL ELEVATION MAP

The DEM map shows Ibese and part of Ilaro to be the highest area in Egbado south, while the lowest area falls majorly in the Idogo area as shown in fig 6 above. For water flow, water move from a high area to a low area i.e. areas of lower elevations have a higher probability of getting flooded than areas of higher elevations (Otokiti et al., 2019), except in the cases of land use pattern disorder and other human activities which may destruct the natural flow, such areas are meant to be free from flooding.

SLOPE MAP

Low-sloped areas (areas with low slope angles) have a higher susceptibility to flooding than areas with high slopes (high slope angles) (Komolafe et al., 2020; Otokiti et al., 2019). In this study, the slope angle ranges from 0 degrees to 2.1 degrees. From fig 8 the slope angle was classified into very high, high, medium, and low.

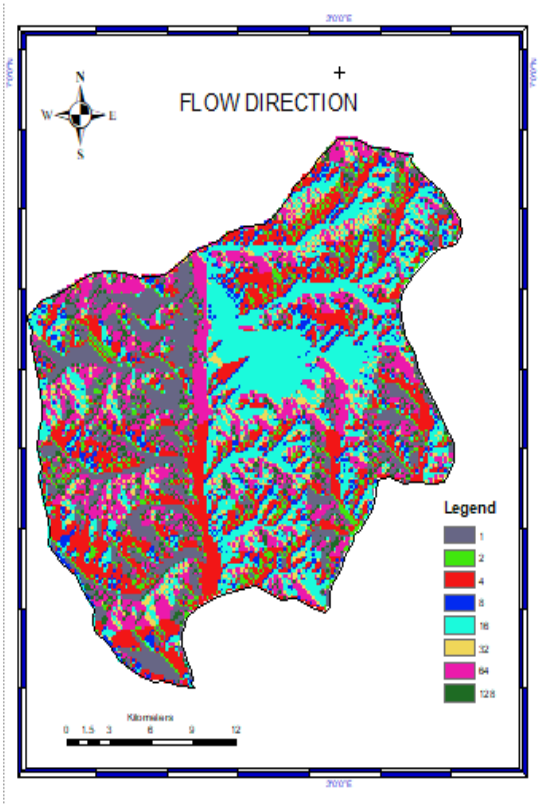


Fig 7: Flow direction map of Egbado south

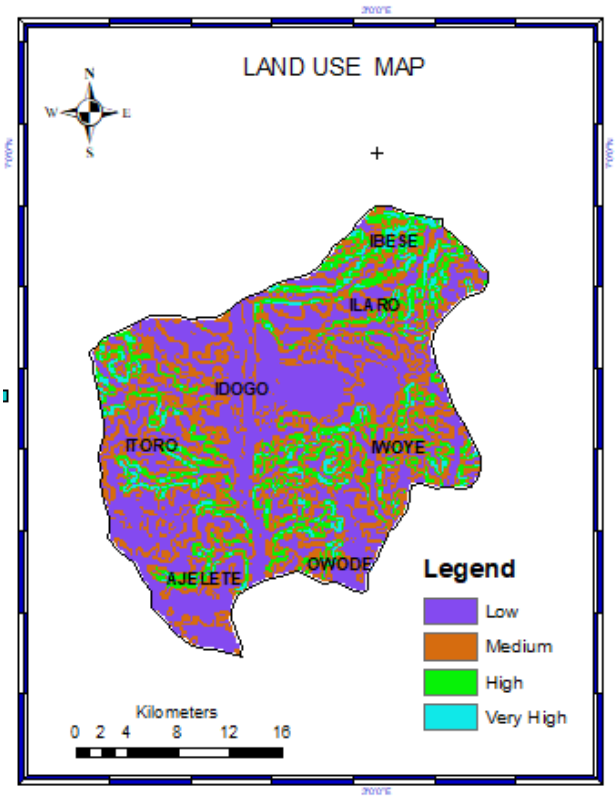


Fig 8: Slope map of Egbado south

FLOW DIRECTION MAP

Flow direction shows the direction of water flow in a particular cell. Based on the direction of the steepest descent in each cell, the flow direction is determined. From fig 7 and fig 9 the numbers are code representing flow pattern

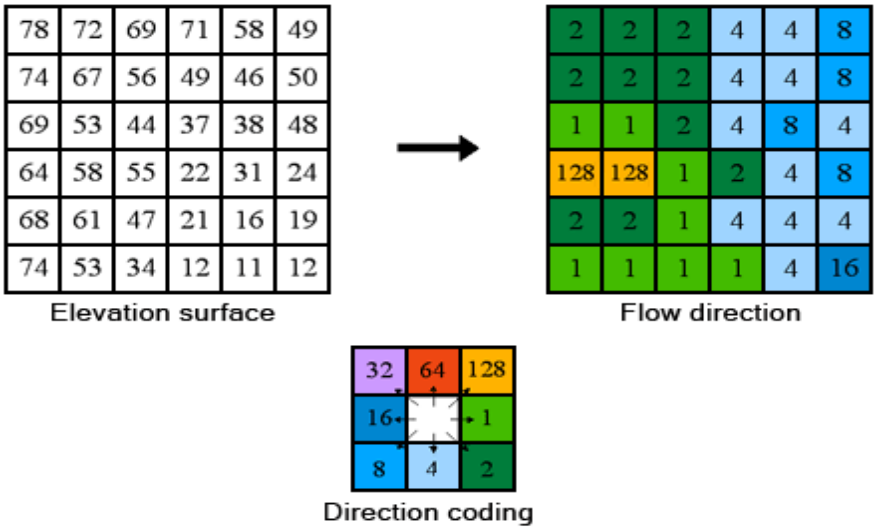


Fig 9: Flow direction code source: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-flow-direction-works.htm

FLOOD RISK MAP

The flood risk chart of Egbado south in fig 11 below showed the low flood risk zone to be 2%, 81% of the medium flood risk zone covers a larger percentage of the area, and the high flood 17%. Fig 10 shows the flood risk map

classified into 3, High, Medium, and Low. From the map, the whole of Egbado south only has a high flood risk area of 17% which shows that if planning is enforced and updated lesser disasters will occur from flooding. However, a larger percentage of the study area falls within the medium flood risk zone and that is a concern if not properly planned for. This map can serve as a tool for policymakers in decision-making, to reduce the infrastructural growth in the flood risk zone.

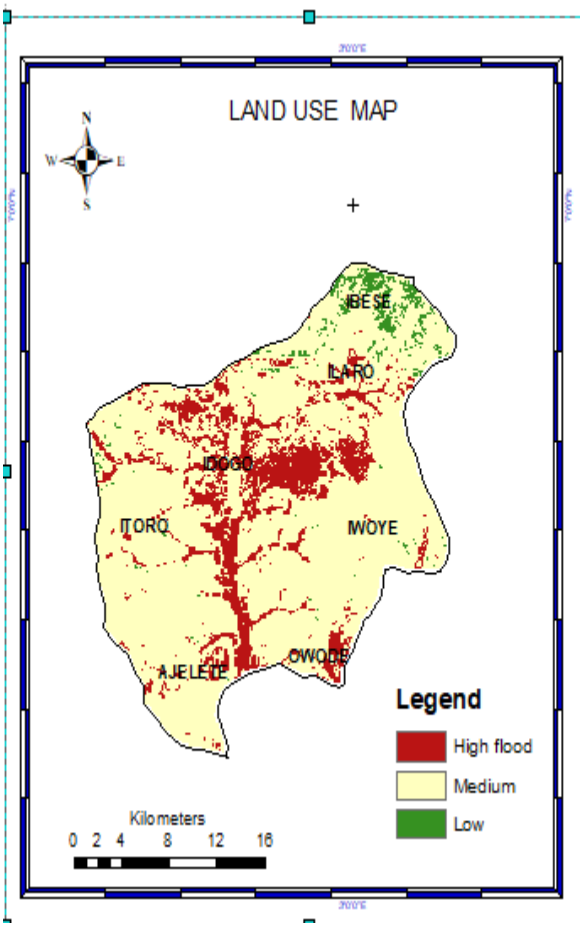


Fig 10: Flood Risk Map

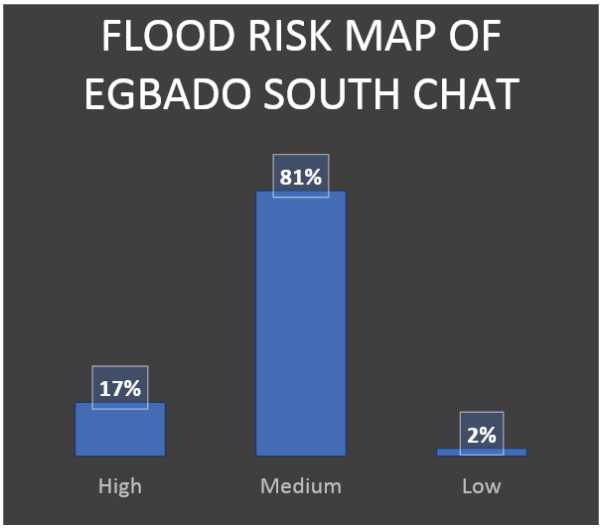


Fig 11: Flood risk chat

5.0 CONCLUSION

The findings as shown in the flood risk map of the area produced in fig 10, Ibese and part of Ilaro fall within the low flood risk zone of 2%, 81% of the medium flood risk zone covers a larger percentage of the area, and the high flood 17%. Adopting the findings of the study for flood control and management in various processes for sustainability and the need to increase planning cannot be underestimated. The map as shown in fig 10 will serve as a basic tool for policy development and implementation for flooding which will reduce the risk to the infrastructure exposed, this map is more reliable because of its spatial content. From the result obtained it has to be considered if the images as shown in fig 1- fig 3 will be controlled to avoid further exposure to flooding risk.

5.1 RECOMMENDATIONS

The following were recommended

1. Urban sprawl should be controlled by the planning authority
2. Policies should be reviewed to accommodate the effect of new development.
3. Only four factors were used for the production of the flood risk map, more factors can be used in further studies

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