GEOGRAPHICAL INFORMATION SYSTEM (GIS) AND ANALYTICAL HIERARCHY PROCESS APPROACH FOR DETECTING OF FLOOD HAZARDOUS AREAS IN YEWA SOUTH, OGUN STATE

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Abstract

Many countries, including developed, developing, and underdeveloped ones, are at risk from floods. Floods have become one of Nigeria's most destructive natural disasters due to several factors which include the effects of climate change, changes in land use, elevation changes., etc. Flood risk is a byproduct of both natural and human activities, necessitating an immediate and improved understanding of its spatial breadth and length. This study attempts to locate and map flood-prone sites in the Yewa (Egbado) South Area of Ogun state. 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. To create a flood hazard map for the area, the Analytical Hierarchy Process (AHP) assigned weight and ranking based on the level of impact the criteria have on flooding; they were used to create a weight overlay comparative map of these criteria. The result shows that part of Ibese and a portion of Ilaro are in the low flood hazard zone, have a 2% risk of flooding, while a larger portion of the area is covered by the medium flood hazard zone (81%), which has a 4% risk of flooding. The high flood zone has a 17% risk of flooding, according to a weight overlay comparative map of these criteria.

Keywords: Flood hazard, Geographical Information System, AHP, weight overlay,

INTRODUCTION

In a study reported by Jung et al., (2014), countries around the world including developed, developing, and underdeveloped ones, are at risk from floods. As a result, the Federal Emergency Management Agency (FEMA) of the United States has established a flood management program to manage this hazard. Jung et al., (2014) further explained that the program uses digitally formatted flood maps to assess potential flood risks and the associated insurance rate that is subject to government regulation. Furthermore, due to a lack of resources to repair property damages, developing nations that face flood risk sometimes take longer to recover from natural disasters

(Allafta & Opp, 2021). In Pakistan, flood disasters occur almost every year, primarily during the monsoon seasons, which significantly damage livelihood, properties, settlements, roads, animals, and agricultural fields. Flooding in particular has significantly hurt Pakistan's economy (Zehra & Afsar, 2016). Numerous individuals lost their lives as a result of the severe floods in the parts of Pakistan around Indus, Kabul, and Swat Rivers. These also caused significant damage to settlements, infrastructure, crops, and river embankments (Zehra & Afsar, 2016).

Also, Ouma and Tateishi, (2014) reported a study over Eldoret Municipality in Kenya, where it was discovered that due to increased produce runoff and shorter concentration times, tiny streams in urban areas can rise quickly after heavy rain. An approach which integrated GIS and AHP to create a map of the flooding hazard, flooding-causing factors like rainfall distribution, elevation and slope, drainage network and density, land-use/land-cover, and soil type was to be considered.

The rising number of flood victims and the limitations on sustainable development brought on by flooding in the nation shows that many of the solutions now known to address flooding in the nation fall short (Ugonna, 2016). According to Usigbe (2021), 30 out of 36 states in Nigeria were impacted by floods in 2012 alone, displacing nearly 1.3 million people and claiming over 400 lives. Therefore, it is crucial to continuously assess the impact of this hazard as it remains a threat to many communities.

Ouma and Tateishi, (2014) explained that flood hazard comprises vulnerability and risk. It defined hazards as potentially dangerous events or threatening occurrences that take place in a specific location and at a specific time. When an event is said to be dangerous, the damage must have taken place, and the level of damage depends on the hazard aspect. These components include the populace, the physical environment, the economy, etc. Contrarily, vulnerability is the most important element of risk since it determines whether or not exposure to a risk qualifies as a risk that could cause a disaster. As a result, numerous studies have been conducted to assess the degree of vulnerability in various regions throughout the world to flooding; nevertheless, given the dynamic influence of flooding, even more research is needed (Barroca et al., 2006). The relationship between flood vulnerability and total asset value at risk for flooding is known as the "flood risk" formula. The probability of all flood threats combined and the assets that are vulnerable to these hazards are used to calculate flood risk.

Flooding has become one of the most frequent natural disasters in the world due to human migration into floodplain areas to secure land for habitation or inhabit affordable dwellings. The rate and intensity of this natural hazard have increased with the world's population growth and urbanization (Oladejo & Taiwo, 2018). Komolafe, Akinola, Adegboyega and Akinluyi (2015) further stated that floods can be caused by both natural and man-made factors. Natural factors include high rainfall and coastal storms, while man-made factors include burst water main pipes, inadequate drainage systems, patterns of land use, failed dams, and illegal garbage disposal. As illustrated in Figure 1A, flooding is a serious problem in Lagos state, one of the many states in Nigeria that are prone to this natural calamity, and it has repeatedly been connected to the rate of urbanization (Dorcas & Wendy, 2021). The development of land within the flood-prone zone has affected the coastline geometry in Lagos. Dorcas and Wendy (2021) averred that one of the main responsibilities of planners and policymakers is to monitor the rate and pattern of urban growth. According to this evaluation, there is a critical need for ongoing planning and updating. Additionally, the dearth of adequate and trustworthy data from Nigeria's "standard" hydrology and climatology justifies this need.

Figure 1: A-Flood in Lekki phase 1 area Lagos state and B- Flood in Ifo area of Ogun state

Source: Fieldwork, 2021

Data can be viewed, understood, questioned, interpreted, and visualized in a variety of ways that show relationships, patterns, and trends using maps or images as appropriate. GIS will serve as an important tool for this, and further make a useful component in flood hazard assessment. Additionally, many people have used spatial analysis in the GIS environment to estimate flood hazard zones. The interpretation of flood-prone areas into any information system framework is possible due to the availability of remotely sensed data, which keeps the GIS tools useful for addressing problems related to the earth (Alausa & Adaradohun, 2018).

AHP analysis results can be mapped using GIS, which has developed into a potent information integration system. To achieve a meaningful decision-making process, the Analytic Hierarchy Process (AHP) has been developed into a valuable instrument for qualitative and quantitative assessment (Lyu et al., 2018). It has become a helpful instrument for decision-making and analysis. Generally, AHP is a theory and methodology for relative measurement. In the relative measurement, a pairwise comparison method (PCM) is built following a scale of relevance since there is no interest in the precise measurement of specific quantities but rather in the proportions between them (Faregh & Benkhaled, 2021).

A flood hazard map of Egbado south in Ogun state was produced showing the flood hazard areas, this was necessitated due to the flood event that had occurred, severally during major rainfall episodes, as shown in Figure 2. A map is a crucial tool for determining how vulnerable flood-prone areas are. To estimate flood hazard zones, spatial analysis in a GIS context has been used. Four relevant physical factors—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 determine the weight values (in AHP). To produce a weighted overlay map, the flood hazard zones within the study area have been mapped according to their weights.

Figure 2: Flood in Ilaro, Ogun state

Source: Fieldwork, 2021

Figure 3: A &B- Flood in Oju ore road, Sango Ogun state.

Source: Fieldwork, 2021

Study Area

The area of study is called Yewa South (formerly Egbado South). It is a Local Government Area (LGA) in Ogun state, Nigeria. Ilaro town serves as the LGA's administrative center. Important towns within the LGA include part of Ibese, Ajilete, a part of Owode, Itoro, Iwoye, Idogo, Oke Odan, and Ilaro. Yewa south is about 629 km^2 in size, with a population of 168,850 living there as of the 2006 census. The study area is largely filled with agriculture focused indwellers as the land mass yields lots of agricultural products like cassava and corn. The Yewa south (Egbado South) Local Government Area (LGA) was founded in 1976 and is located between longitudes 2° 48' 59.148" E and 3° 5' 30.732" E; and latitudes 6° 37' 10.848" N and 6° 56' 38.004" N (Google Maps, 2023; Furey, 2023) (see Figure 4).

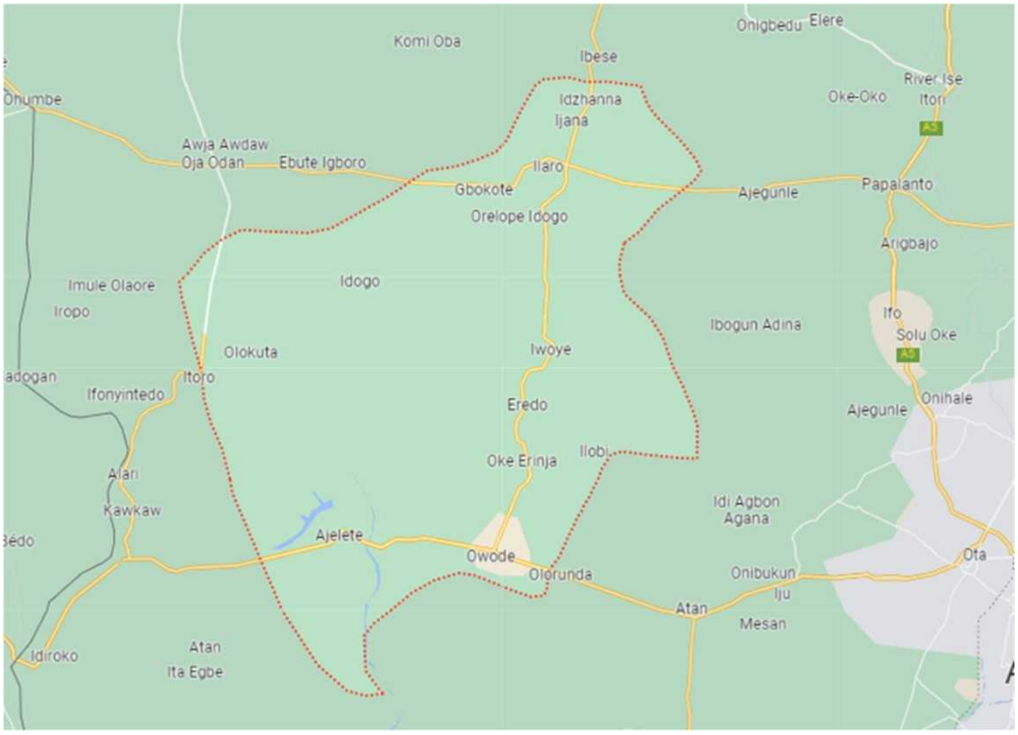

Figure 4: Yewa south (Egbado south) local government area

Source: (Google Maps, 2023)

METHODOLOGY

In 1980, Saaty proposed the use of AHP to analyze problems while taking several elements into account (see Figure 5). In this study, the flood danger map was created using the pair-wise comparison method (Faregh & Benkhaled, 2021).

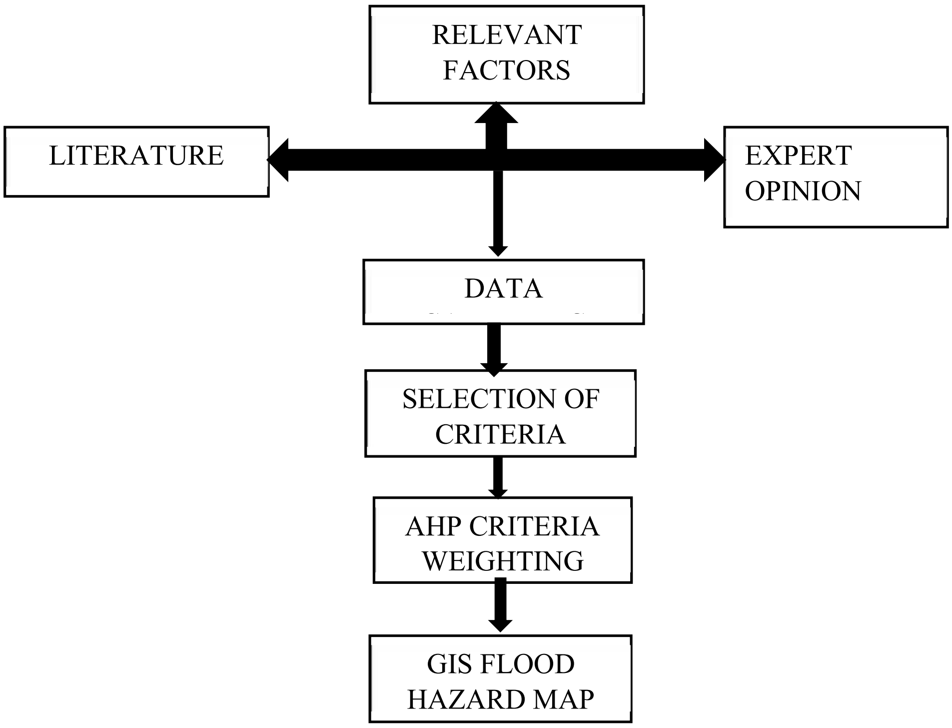

Figure 5: Methodology flowchart

Source: (Lawal et al., 2012)

Data Collection 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 hazard map. The following factors are considered in Table 1, 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/

Source: Fieldwork, 2022

Data Processing

The ArcGIS 10.6.1 was used for the processing of all the acquired data, the slope and flow direction are sub criteria to the digital elevation, they were generated using the raster processing tools in the ArcGIS environment, using the boundary shapefile the area needed was clipped out. Using the multi criteria AHP approach, the Priorities among the Decision Elements of the Hierarchy was done at this stage utilizing a pairwise comparison technique, and a rating scale of relative relevance to collect ratings for each of the criteria and options. The pairwise comparison approach is presented in a matrix as shown in Table 2.

Subsequently, the normalized values for each criterion and alternative were calculated; and the normalized primary eigenvectors or priority vectors (herein also referred to as relative weights) were identified. The value for each cell is divided by its column total to determine the normalized values for each criterion and alternative in their corresponding matrices. Each criterion and option receive a column total of 1 as a result of this process. Before making a choice, these processes are required to calculate the consistency ratio and ascertain the consistency of the evaluation: Calculate each criterion's or alternative's greatest eigenvalue, consistency index, consistency ratio, and normalized values. It is considered that if the ratio is more than 0.1, the collection of judgments may be too erratic to be trusted. Therefore, a CR lower than 0.1% or 10% is acceptable (Allafta & Opp, 2021).

Decision Matrix

Decision hierarchical structure includes the decomposition of the complex decision problem into smaller manageable elements of different hierarchical levels/layers. The calculation under this was done using the online calculator (Goepel, 2022). The resulting weights are based on the principal eigenvector of the decision matrix as shown in Table 3.

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 resulting weights are based on the principal eigenvector of the decision matrix:

Data in Tables 2 and 3 where generated from the online calculator (Goepel, 2022)

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

Source: Fieldwork, 2022

AHP weight Priorities

The resulting weights for the criteria based on the pairwise comparisons for Yewa south are as shown in Table 3.

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% To complete the weighted overlay computations and include the weighted parameters for the flood hazard mapping, a value of CR (less than 10%) is acceptable (Allafta & Opp, 2021).

RESULTS AND DISCUSSION

To create a flood hazard map, the weighted overlay tool in ArcGIS 10.6 was used in conjunction with the prioritized weights derived in Table 3 to perform a weighted overlay analysis. The series of maps created and superimposed to make Figure 11 are shown in Figure 6 through 9.

Land Use Land Cover Map

The water, vegetation, built-up areas, and barren ground were the four categories into which the land use and land cover map were divided. A large portion of the water land covered by vegetation is categorized along with vegetation area on the map, which demonstrated that Ilaro is the LGA's most developed area. The local government area of Yewa South has the highest proportion of vegetation coverage, as seen in Figure 6, indicating that the majority of its population work in agriculture.

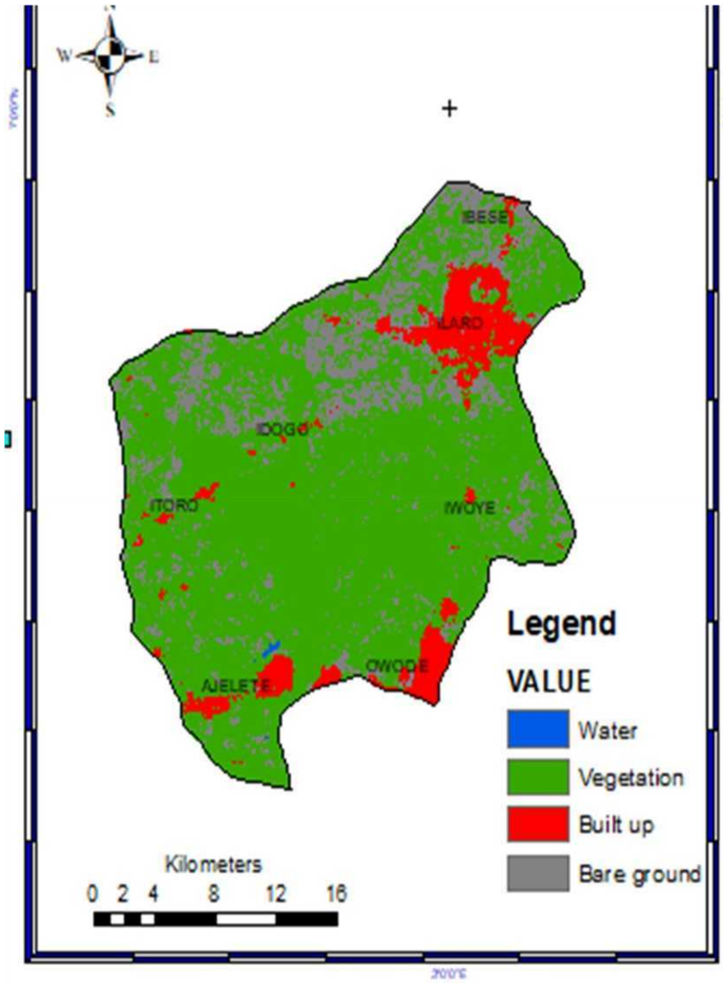

Figure 6: Land use land cover map of Yewa south

Digital Elevation Map

Ibese and a portion of Ilaro are the highest areas on the DEM map in Egbado south, whereas the Idogo area, as indicated in Figure 7, has the lowest areas. Regions with lower elevations have a higher likelihood of flooding than areas with higher elevations because the water flows from a high area to a low area (Otokiti et al., 2019). Such places are intended to be free from floods, excepting extreme situations of land use pattern disorder, and other human activities that may disrupt the natural flow (Figure 8).

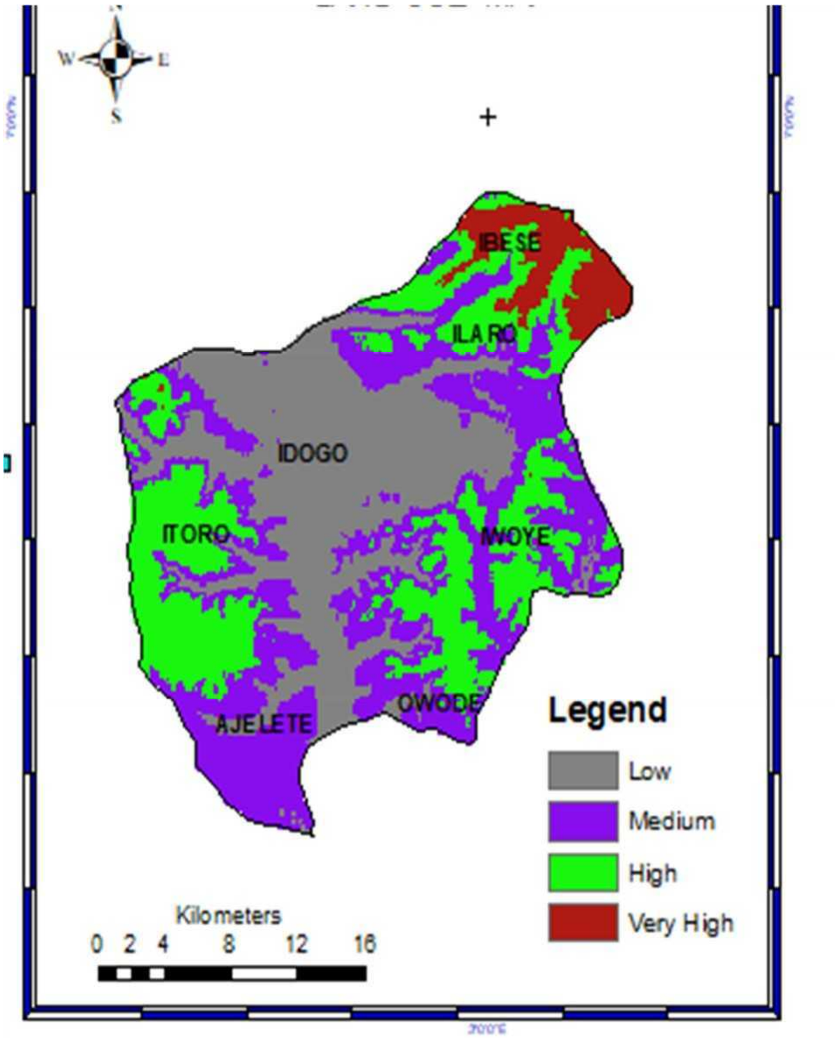

Figure 7: Elevation map of Yewa south

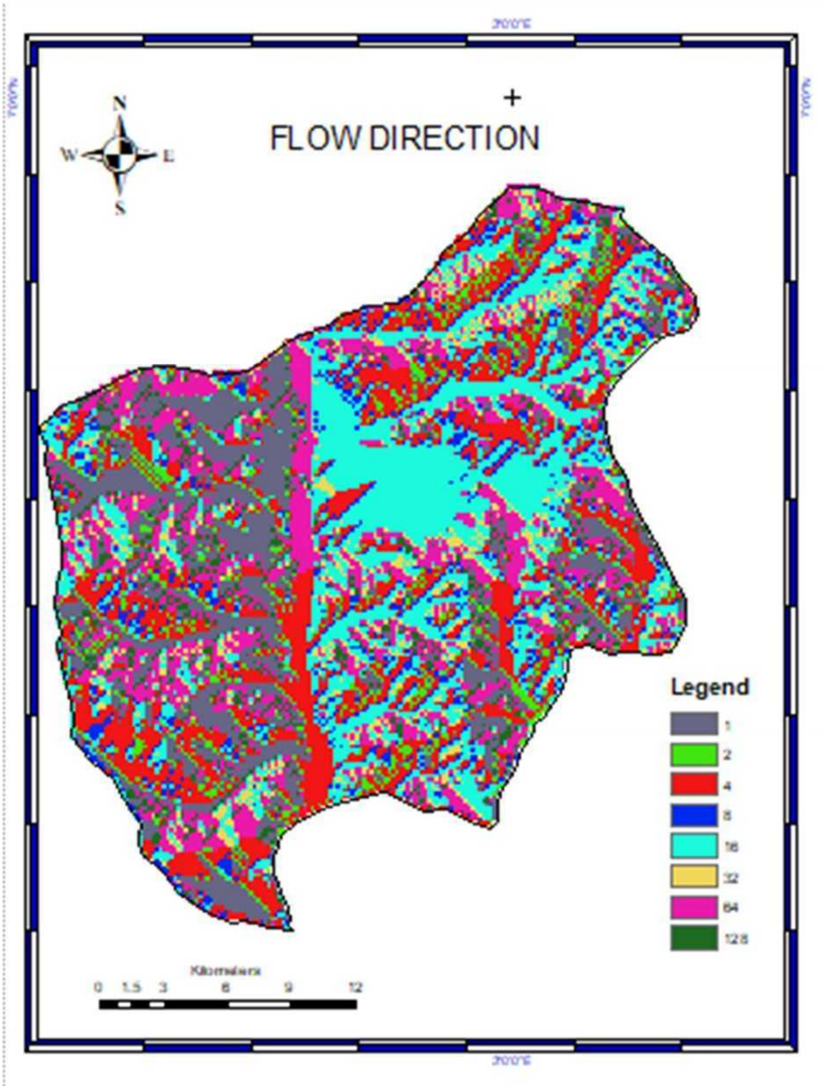

Figure 8: Flow direction map of Yewa south

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. As shown in Figure 8, the slope angle was classified into very high, high, medium, and low.

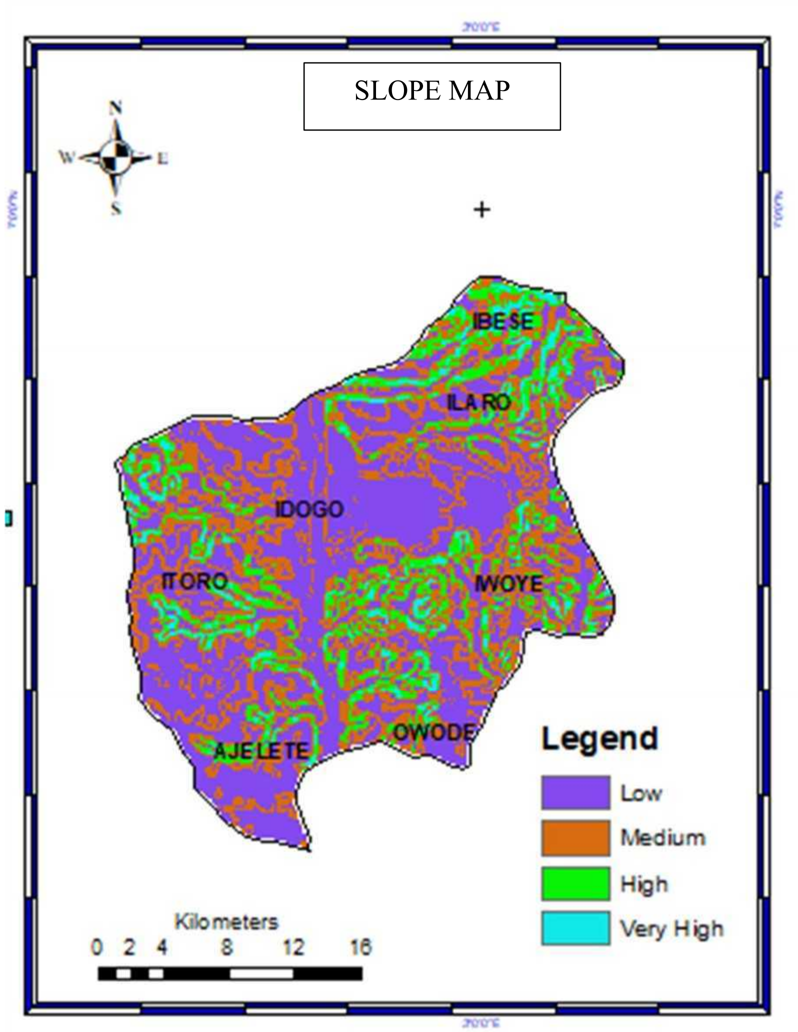

Figure 9: Slope map of Yewa south

Flow Direction Map

The direction of water flow in a certain cell is indicated by flow direction. The flow direction is calculated from the direction of the steepest slope in each cell. The numbers in Figure 8 and 10 represent the flow pattern.

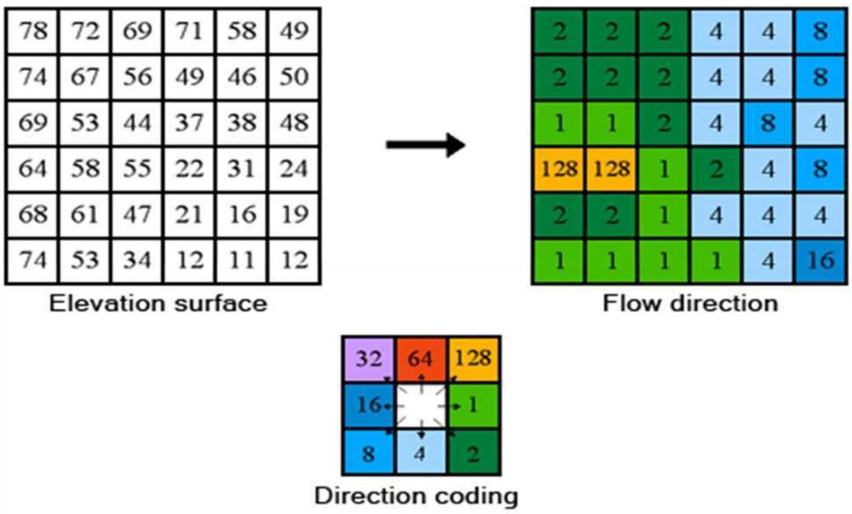

Figure 10: Flow direction code

Source: (ArcGIS, 2023)

Flood Hazard Map

The low flood hazard zone for Yewa South is shown in Figure 12 to be 2%, the medium flood hazard zone is shown to be 81%, and the high flood zone is shown to be 17%. The flood hazard map in Figure 11 is divided into three categories: High, Medium, and Low. According to the graphic, only 17% of Egbado South is in a high flood hazard area, demonstrating that flooding disasters can be reduced if planning is implemented and kept up to date. A bigger portion of the research area does, however, lie inside the medium flood hazard zone, which raises questions if it is not appropriately planned for. This map can be used as a decision-making tool by policymakers to slow the expansion of infrastructure in flood hazardous zone.

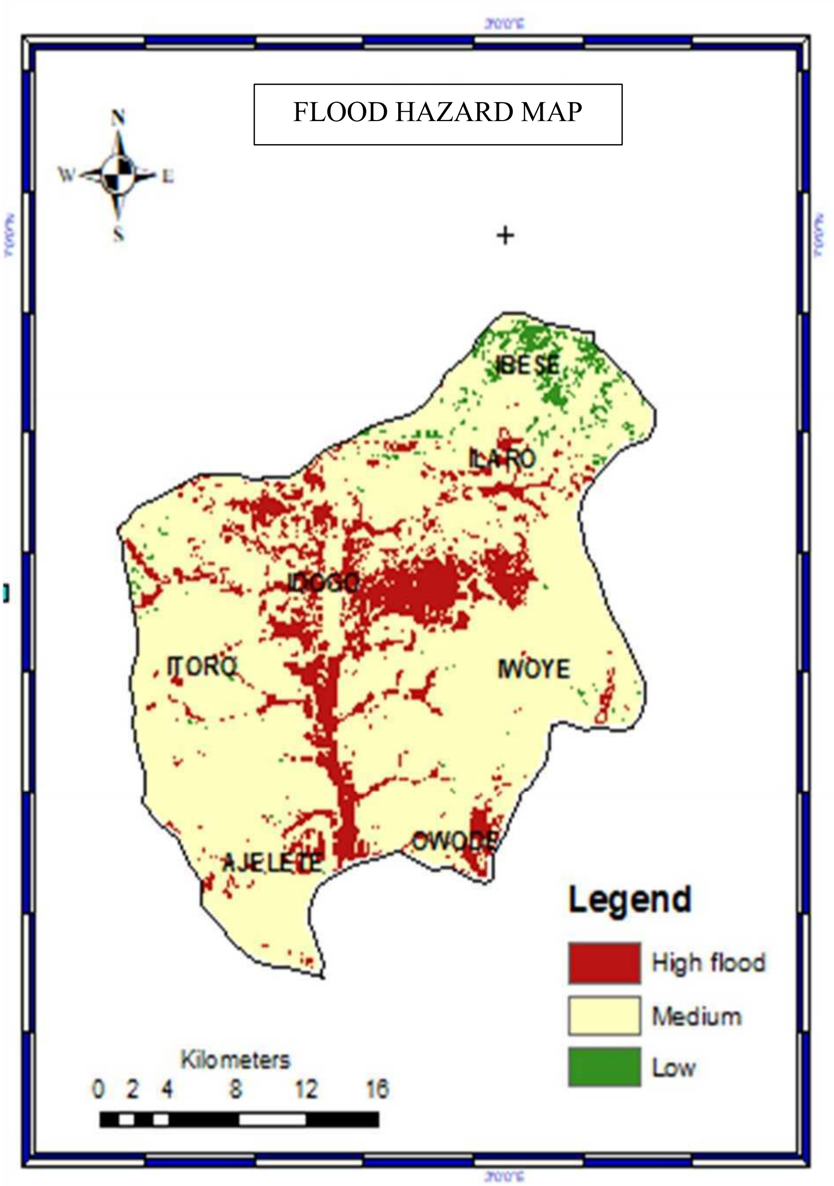

Figure 11: Flood Hazard Map

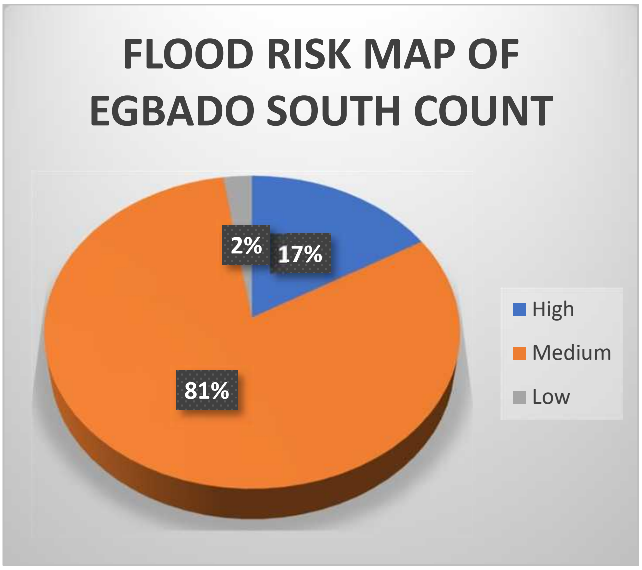

Figure 12: Flood hazard chart

CONCLUSION AND RECOMMENDATIONS

The results of this study have a significant impact on decision-making if it aims to be sustainable and increase the need for planning that tends toward flood control and management; the map depicted in Figure 11 will serve as a fundamental tool for policy development and implementation for flooding that will reduce the risk that infrastructure is exposed to, and this map is more reliable due to its spatial content. If the images in Figures 1 and 3 are to be controlled to prevent further exposure to the flooding risk, the aforementioned must be taken into account. Consequently, it is suggested that the State and Local planning authorities should put in place measures to manage urban sprawl. Towards this, policies should be revised and an audit of the impact of recent developments conducted. Equally, whereas, the flood hazard map was created using only four parameters, additional components could be utilized in future research.

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