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SATELLITE BASED IMAGERY VARIATIONS IN ANNUAL RAINFALL AND INTENSITY OF FLOOD SUSCEPTIBILITY IN ANAMBRA WEST NIGERIA, USING INTEGRATING GIS

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ABSTRACT

This study adopted a quantitative, spatially-based research design leveraging Geographic Information System (GIS) and Remote Sensing (RS) technologies. The aim was to analyze, visualize, and predict flood vulnerability zones in Anambra West, Nigeria, using geospatial techniques. The design included systematic data acquisition, processing, integration, classification, and multi-criteria weighted overlay analysis. The work produced a multi-temporal flood vulnerability map spanning the years 2019 to 2023. The flood susceptibility map were classified into three flood risk levels: Low Risk**,** Moderate Risk **and** High Risk. The geospatial multi-criteria decision analysis (MCDA) approach was adopted, combining environmental and anthropogenic variables such as rainfall intensity, slope, elevation,

distance to river, distance to road, drainage density, and land use/land cover (LULC). These parameters were reclassified into standardized classes and assigned weights based on their relative contribution to flood risks in the area. The research was structured into four phases: Data acquisition, Data pre-processing (projection, clipping, and raster alignment), Spatial and statistical analysis and Visualization and interpretation (map production and analysis).

The year 2019 showed a low risk class of 38.4%, a moderate risk class of 49% and a high risk class of 11.9%. The second year which is the year 2020 showed a low risk class of 31.6%, a moderate risk of 52% and a high risk of 16.0%.

For the third year which is year 2021, a low risk class of 36.1%, a moderate risk of 50.8% and a high risk of 13.0% was discovered. Again year 2022 indicated a low risk class of 28.%, a moderate risk of 53.6% and a high risk of 17.5% where the year 2023 showed a low risk class of 22.5%, a moderate risk class of 58.2% and a high risk class of 19.3%. The research has fairly created a map through which Anambra West region can be recovered from the increasing flood disaster that it has suffered for many years.

1.2 Research Problem

Despite the consistent work done recently using artificial intelligence and some traditional methods of flood imagery prediction , effective flood mapping is not yet achieved especially in the cases where past flood events is required to fine tune advanced research in communication engineering like artificial intelligence. Thus, the **integration of** GIS and weighted overlay methods is vital for **V**ariations in Annual rainfall as affecting the extent and intensity of flood susceptibility.

1. 3 Aims and Significance of this Research

The aims of this paper is three folds

- To conduce 5 years temporal flood risk assessments for Anambra West Nigeria.
- To create rainfall scenarios that can be used for Disaster management planning .
- To develop a model that will aid policy formulation, land use regulation, and emergency response planning.

The significance lies on producing flood susceptibility and historical data set for past flood events in Anambra West Nigeria in order to foster flood mitigation nitty-gritty and to offer researchers in the same context of study the better foundation for future communication engineering in flood related programs.

2. Related Literature

Globally Flood hazards are known as a phenomenon, but their disastrous effects are most severe in developing countries where 1.81 billion people, or 23% of world population, are exposed to considerable flood risks, the (Boadi et al., 2025, Chen et al., 2024, Rentschler et al., 2022).

The severity ,duration, and frequency of disastrous floods are increasing, primarily due to population and by climate change (Devitt et al., 2023; Prabandaru et al., 2021).

In recent decades, many research works have utilized Remote Sensing (RS) data and Geographic Information Systems (GIS) combined with various models and methods to produce flood susceptibility maps (Kaya And Derin,2023). Several methods have been developed for flood susceptibility assessment, with successful application globally. (Zhao etal., 2025, Zhou etal., 2024), physically- based hydrological models (Hussain et al., 2023; Tariq et al., 2024), statistical methods (Zhou et al.,2022). Each of these methods has its advantages and limitations, and their effectiveness is influenced by the selected flood conditioning factors as well as the specific case study (Ahmed et al., 2023). Among these methods , the most commonly and widely used are the expert's knowledge-based MCDM, Analytical Hierarchy Process (AHP) model (Li etal., 2024). Due to their ease of application, compatibility with GIS, and ability to produce accurate results.

There has been sharp increase in demand for flood susceptibility mapping. Anambra West is one of the worst regions affected by flooding in Nigeria West Africa considering the fact that in the year 2012 the government of the State lamented the increase rate of flooding which had claimed many lives and properties in the region.

This study adopted a quantitative, spatially-based research design leveraging Geographic Information System (GIS) and Remote Sensing (RS) technologies. The aim is to analyze, visualize, and predict flood vulnerability zones in Anambra West, Nigeria, using geospatial techniques.

4. Study Area

The study area for this project is Anambra West Local Government Area (LGA), located in the northwestern part of Anambra State, Nigeria. Geographically, Anambra West lies approximately between latitude 6°20'N to 6°40'N and longitude 6°30'E to 6°50'E. It is bounded to the north and west by Kogi State, to the east by Anambra East LGA, and to the south by Ogbaru LGA.

Anambra West is primarily situated in a low-lying floodplain of the Lower Niger Basin, making it one of the most flood-prone regions in Southeastern Nigeria. The area comprises numerous river channels, including tributaries of the River Niger and Omambala River, which serve as the major hydrological features influencing seasonal and flash flooding patterns.

5. Flood Susceptibility Maps of the year (2019–2023)

Below, are the flood maps produced using the weighted overlay technique:

5.1: Flood Susceptibility Map of the year – 2019

This presents the flood susceptibility Map of Anambra West, Nigeria for the year 2019

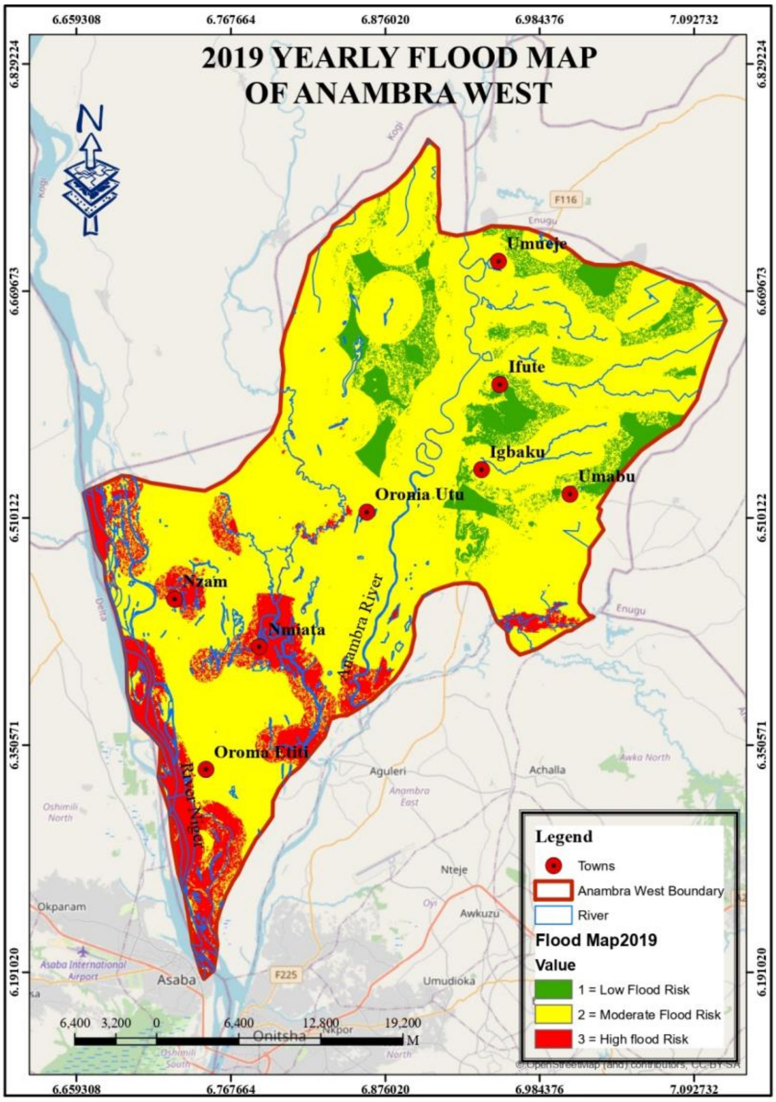

Figure 1: Flood Susceptibility Map – 2019.

5.2 The scenario presents the Flood Susceptibility Map of Anambra Anambra West for the year 2020

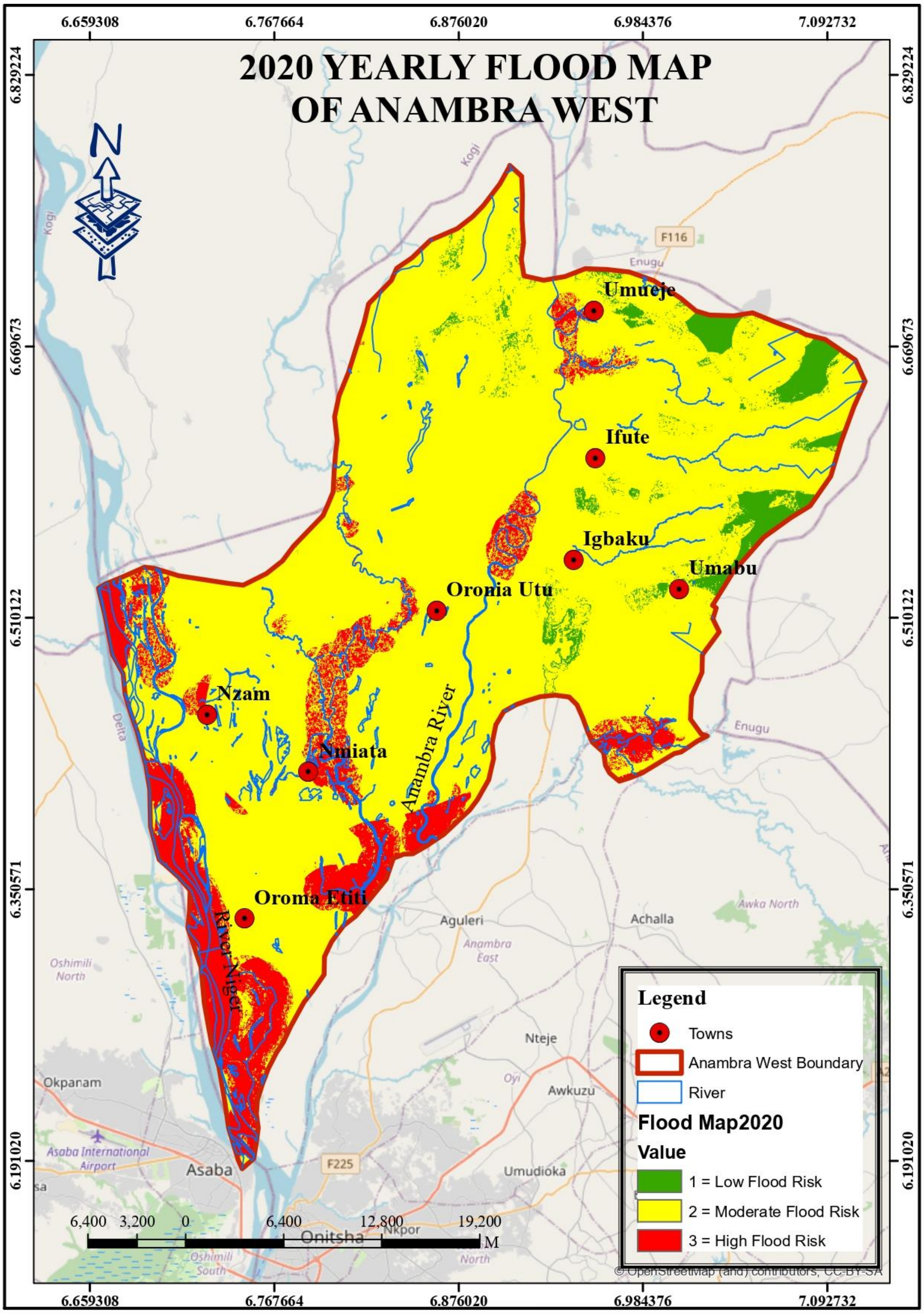

Figure 2: Flood Susceptibility Map – 2020.

5..3 The scenario present s the flood susceptibility map of Anambra West, Nigeria, for the year 2021

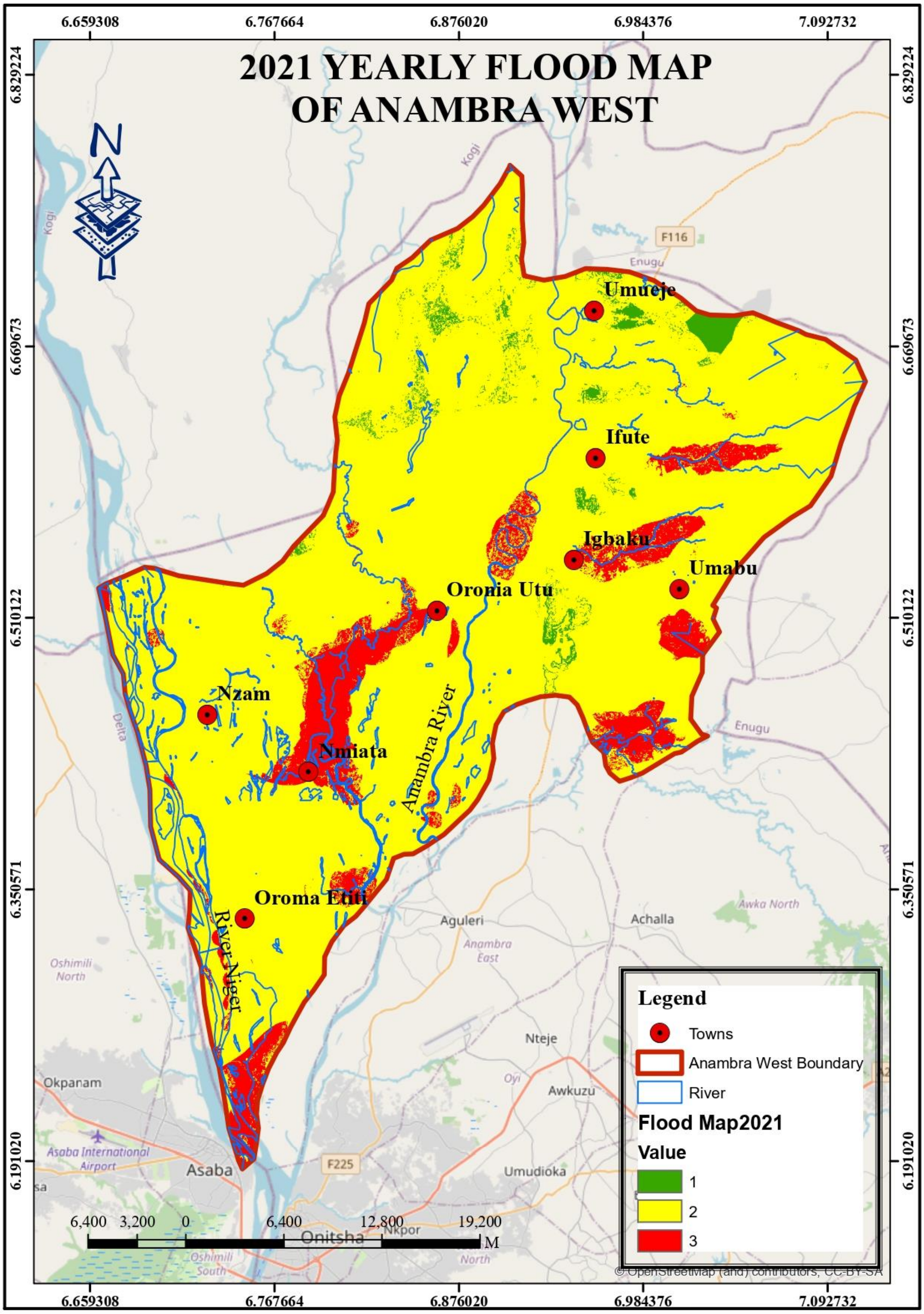

Figure 3: Flood Susceptibility Map – 2021.

5.4 This scenario presents the flood susceptibility Map of Anambra West for the year 2022

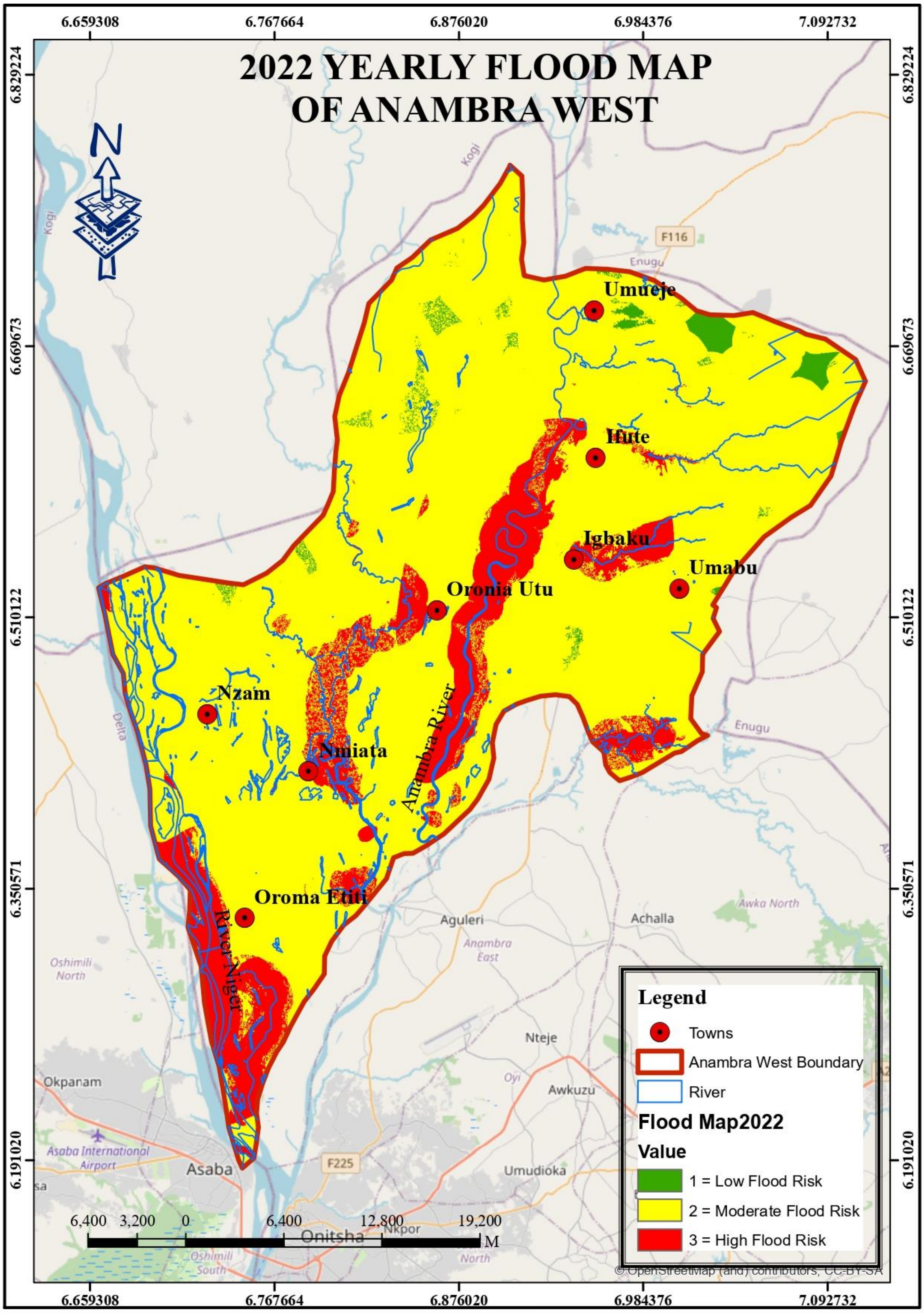

Figure 4: Flood Susceptibility Map – 2022.

5.5 This presents the flood susceptibility map of Anambra west for the year 2023

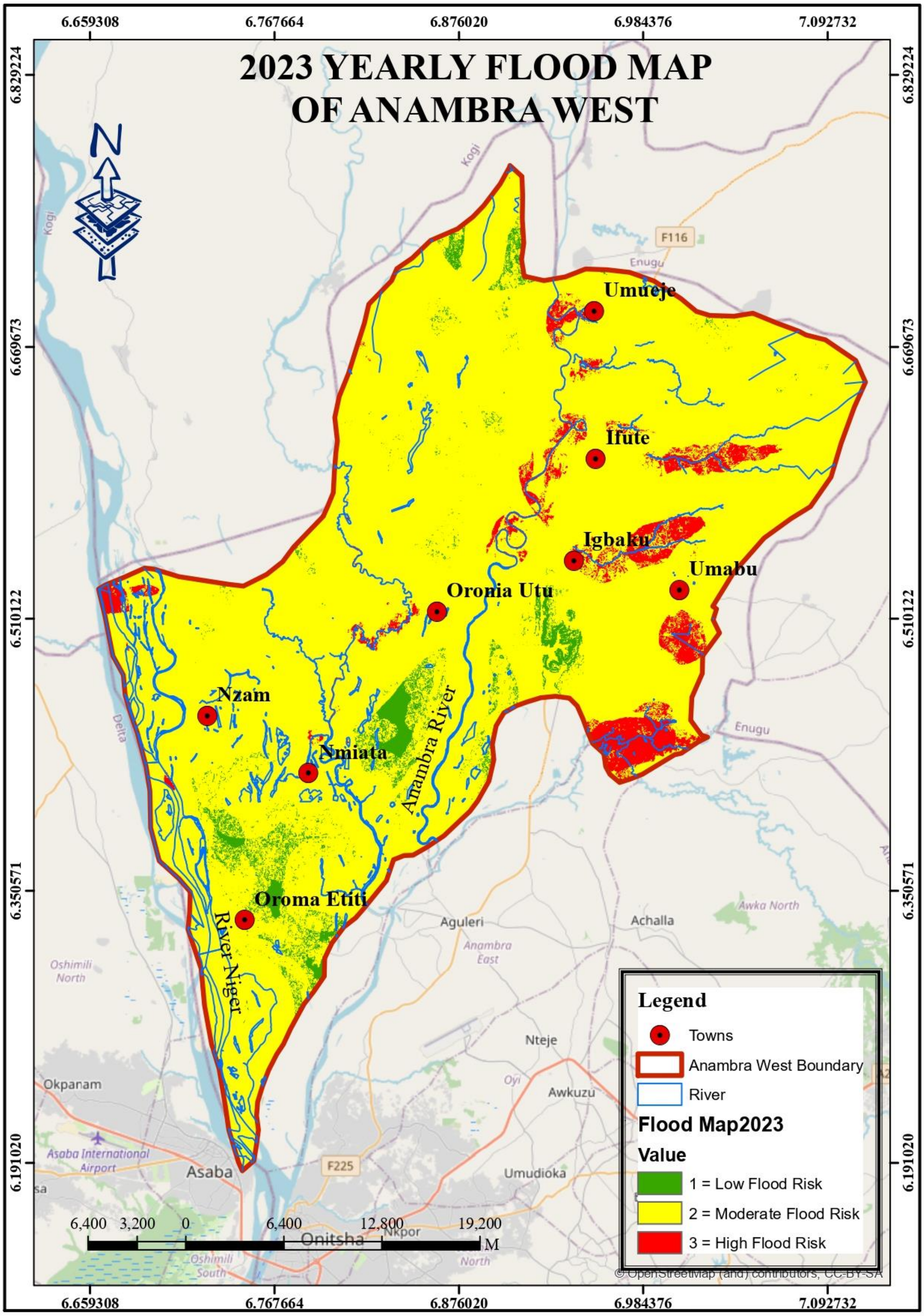

Figure 5: Flood Susceptibility Map – 2023.

6. Flood Susceptibility Map Analysis (2019–2023)

1.Classified into three flood risk levels:

- **Class 1 (Green): Low Risk**
- **Class 2 (Yellow): Moderate Risk**
- **Class 3 (Red): High Risk**

6.1 2019 Flood Susceptibility Analysis

In 2019, rainfall intensity was relatively low, especially in September, leading to more stable hydrological conditions in Anambra West. The flood risk map reflects this, with:

- **High flood risk areas (Red)** mostly confined to **riverbank communities** such as **parts of Nzam, Inoma, and Odekpe.** These are low-lying and close to River Niger.
- **Moderate risk zones (Yellow)**formed the largest portion, especially around **Mmiata and Umuenwelum.**
- **Low risk zones (Green)**dominated higher elevation areas, particularly in the**northeastern parts of the LGA.**

  The low rainfall in 2019 limited the spatial extent of high-risk areas, with flood hazards restricted to floodplains.

6.2 2020 Flood Susceptibility Analysis

The year 2020 saw a moderate increase in rainfall, especially in June and September. This led to an observable expansion in high-risk zones.

- **High flood risk areas** expanded around **Oroma-Etiti, Iyiora, and Inoma.**
- **Moderate risk class** still accounted for over 50% of the landscape.
- **Low-risk areas** decreased slightly due to encroaching flood zones from increased rainfall accumulation.

The increased runoff from elevated rainfall and rising river levels expanded flood susceptibility, particularly in low elevation and poorly drained areas.

6.3 2021 Flood Susceptibility Analysis

In contrast to 2020, **2021 experienced lower rainfall,** particularly during critical months. As a result:

- **High-risk areas** shrank significantly, remaining near **Ifite-Ogwari and Umueje.**
- **Moderate risk class** increased in elevation, spreading into previously low-risk zones.
- **Low-risk areas** slightly recovered.

The flood pattern reflects the buffering role of elevation and slope in flood moderation. Less rainfall meant that only naturally flood-prone areas experienced risk.

6.4 2022 Flood Susceptibility Analysis

Rainfall intensified again in 2022, with peak values around **September–October.** This is visible in the flood susceptibility distribution:

- **High-risk areas** reappeared and became widespread in **Umuikwu, Mmiata, Umuabiama and surrounding areas.**
- **Moderate risk** was prominent around transition zones, especially **between forested andagricultural lands.**
- **Low-risk zones** persisted only in elevated northeastern parts.

High rainfall and accumulated surface runoff increased flood coverage. Areas with dense drainage networks experienced quicker saturation and surface water accumulation.

6.5 2023 Flood Susceptibility Analysis

This was the **most flood-impacted year**, with **September recording the highest rainfall** across the five years.

- **Class 3 (High flood risk)** areas were extensive, covering **Ifute, Igbaku, and Umaku,** corresponding to areas with:
  - Low elevation
  - Proximity to River Niger
  - High drainage density
- **Class 2 (Moderate risk)** dominated most of the central and southern zones, especially **Nzam, Orona Utu, and Umueje.**
- **Class 1 (Low risk)** was minimal and restricted to the highland fringes.

The interplay between **intense rainfall, high runoff,** and **limited drainage capacity** made 2023 the most critical year for flood vulnerability. The map highlights the urgency for flood preparedness in red zones.

Table 6.1: Flood Risk Class Coverage Comparison The Results of The year 2019 -2023.

Year	Class 1: Low Risk (%)	Class 2: Moderate Risk (%)	Class 3: High Risk (%)
2019	38.4%	49.7%	11.9%
2020	31.6%	52.4%	16.0%
2021	36.1%	50.8%	13.1%
2022	28.9%	53.6%	17.5%
2023	22.5%	58.2%	19.3%

NB: Percentages are approximations based on raster count and cell area calculation.

Key Observations

- **Class 2 (Moderate risk)** is dominant throughout the years, highlighting zones with variable vulnerability.
- There is a **progressive increase in Class 3 coverage**, showing the growing impact of extreme weather and drainage constraints.
- **2023 has the highest high-risk area,** aligning with the statistical peak in rainfall intensity.

7. METHODOLOGY

This study adopted a quantitative, spatially-based research design leveraging Geographic Information System (GIS) and Remote Sensing (RS) technologies. The aim was to analyze, visualize, and predict flood vulnerability zones in Anambra West, Nigeria, using geospatial techniques. The design included systematic data acquisition, processing, integration, classification, and multi-criteria weighted overlay analysis. The end product was a multi-temporal flood vulnerability map spanning the years 2019 to 2023.

The geospatial multi-criteria decision analysis (MCDA) approach was adopted, combining environmental and anthropogenic variables such as rainfall intensity, slope, elevation, distance to river, distance to road, drainage density, and land use/land cover (LULC). These parameters were reclassified into standardized classes and assigned weights based on their relative contribution to flood risks in the area. The research was structured into four phases: Data acquisition, Data pre-processing (projection, clipping, and raster alignment), Spatial and statistical analysis and Visualization and interpretation (map production and analysis).

8. Key Contributions

The research offers a comprehsensive model that government can adopt to combat flood risks and disaster management the Anambra West of Nigeria West Africa.

Additionally the article presents a 5 years flood susceptibility scenerios that helps farmers structure vulnerability mitigation process.

9. CONCLUSION AND APPLICATION

This approach successfully demonstrates how **variations in annual rainfall** affect the extent and intensity of flood susceptibility, using a fixed environmental baseline. By integrating GIS and weighted overlay methods:

- **Temporal flood risk assessments** can be conducted annually.
- **Disaster management planning** can be tailored to specific rainfall scenarios.

- The model aids **policy formulation, land use regulation**, and **emergency response planning**.

The methodology provides a scalable and replicable framework for **early warning systems** and **urban resilience mapping** in flood-prone areas like Anambra West LGA.

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