PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 29 (4) 1015-1022 April 2025

Modeling and Prediction of the Impact of Climate Change on Flooding in Aguata Agricultural Zone, Anambra State, Nigeria

[1]IFEANYICHUKWU, HI; [2]ORAKWE, LC; [3]UBAH, JI; *[4]AWU, JI

[1]*Federal Polytechnic Oko, Anambra State, Nigeria*
[2,3]*Nnamdi Azikiwe University Awka, Anambra State, Nigeria*
*[4]*National Centre for Agricultural Mechanization, Ilorin Kwara State, Nigeria*

**Corresponding Author Email: ecoagricultural@gmail.com*
**ORCID: https://orcid.org/0000-0002-7384-3442*
**Tel: +2348066132929*

Co-Authors Email: hifeanyichukwu2016@gmail.com; louisorakwe@gmail.com; josephikubah@yahoo.com; ecoagricultural@gmail.com

ABSTRACT: Climate change has significantly influenced flooding events, particularly in agricultural zones where extreme weather conditions lead to increased runoff and water accumulation. Hence, the objective of this paper was to model and predict the impact of climate change on flooding in the Aguata Agricultural Zone of Anambra State, Nigeria using Utilizing Digital Elevation Models (DEM), land use data, and climate records, employing Geographic Information System (GIS) and remote sensing techniques to generate flood risk maps. Key hydrological factors, including rainfall intensity, topography, soil infiltration rates, and vegetation cover, were analyzed. The study shows a total flow accumulation of 2,823,864.50 m² and average flow accumulation of 13.81 m², a current mean flood risk of 10.98 mm and total flood risk of 2,244,474.11 mm, and a predicted mean flood risk of 22.12 mm and a total flood risk of 4,523,622.06 mm for the next ten years due to intensified rainfall patterns. The findings emphasize the need for sustainable flood mitigation strategies, improved drainage systems, and climate adaptation policies to minimize the adverse effects of flooding on agricultural productivity in the region.

DOI: https://dx.doi.org/10.4314/jasem.v29i4.1

Cite this Article as: IFEANYICHUKWU, H. I; ORAKWE, L. C; UBAH, J. I; AWU, J. I (2025) Modeling and Prediction of the Impact of Climate Change on Flooding in Aguata Agricultural Zone, Anambra State, Nigeria. *J. Appl. Sci. Environ. Manage.* 29 (4) 1015-1022

Dates: Received: 31 January 2025; Revised: 01 March 2025; Accepted: 20 April 2025; Published: April 2025

Keywords: Climate Change; Flooding; Hydrological Modeling; Rainfall Intensity

Climate change-driven flooding presents substantial threats to agricultural productivity and environmental sustainability (Pimentel and Kounang, 1998). Climate change, characterized by long-term shifts in temperature, precipitation, and atmospheric conditions, has intensified environmental challenges, particularly in agriculture (IPCC, 2014). Among the most critical disasters affecting farmlands is flooding, which threatens food security, land productivity, and local economies (Lal, 2001). Climate change exacerbates these issues by altering rainfall patterns, increasing storm intensity, and raising water levels, leading to more frequent and severe flooding (Nearing *et al.,* 2005). Flooding occurs when excessive rainfall, storm surges, or river overflows inundate agricultural land, damaging crops, displacing farmers, and reducing soil fertility (Montgomery, 2007). Increased rainfall intensity and prolonged wet seasons have significantly contributed to rising flood risks. Heavy rains lead to flash floods and prolonged waterlogging, which degrade soil structure and reduce land usability (Borrelli *et al.,* 2020). Flooding and soil erosion form a vicious cycle, where persistent inundation weakens soil retention, increases runoff, and exacerbates future flood risks. Unchecked, these issues will continue to endanger agricultural zones, making adaptive strategies essential for resilience (Kirkby *et al.,*

**Corresponding Author Email: ecoagricultural@gmail.com*
**ORCID: https://orcid.org/0000-0002-7384-3442*
**Tel: +2348066132929*

2004). In Nigeria‟s Aguata Agricultural Zone (Anambra State), climate change has worsened flooding, severely affecting agriculture (Ofomata, 1985). Increased heavy rainfall has led to frequent floods, resulting in soil degradation, crop loss, and economic hardship for farmers (Okaka and Ogbu, 2019). However, despite recognition of climate change as a major driver of these disasters, the specific mechanisms linking climate change and flooding in this region remain poorly understood. This study aims to investigate these effects using Geographic Information System (GIS).

The objective of this study was to model the impact of climate change on flooding in Aguata Agricultural Zone using GIS technology. This research is significant for: providing data to guide policies on land use and climate resilience, helping farmers adapt to changing flood patterns (Wischmeier and Smith, 1978); identifying conservation strategies to improve water management and prevent flood-related damage; offering localized data to inform climate response measures; highlighting key areas for further study and action; and contributing to Nigeria-specific climate research (Ogunbodede *et al.*, 2022). Hence, the objective of this paper was to model and predict the impact of climate change on flooding in the Aguata Agricultural Zone of Anambra State, Nigeria using Utilizing Digital Elevation Models (DEM), land use data, and climate records, employing Geographic Information System (GIS) and remote sensing techniques to generate flood risk maps.

MATERIALS AND METHODS

Study Area: The Aguata Agricultural Zone, one of the four agricultural zones in Anambra State, Nigeria, is situated in a sub-humid climatic region (Ofomata, *1985*). It covers an area of approximately 534 square kilometers and includes four local government areas: Nnewi North, Nnewi South, Orumba South, and Orumba North as shown in Figure 1.

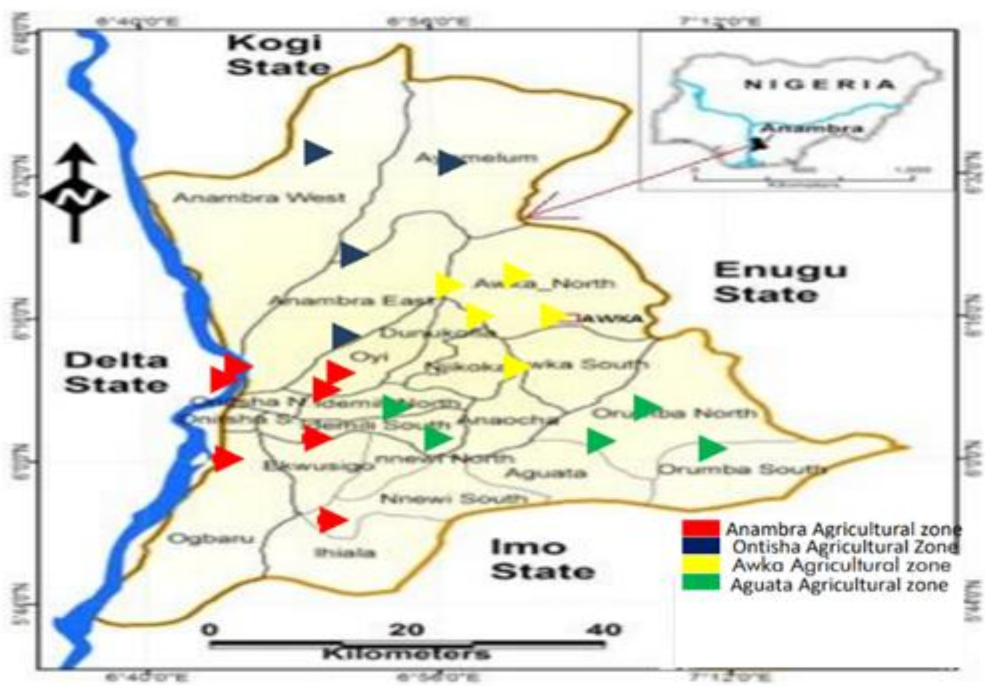

Fig 1: map of Anambra state showing Aguata agricultural zone Source: Ohaturuonye (2022)

The climate is tropical, with a raining season starting from April to October and a dry season starting from November to March. Annual rainfall ranges between 1,500 mm and 2,000 mm, supporting rainfed agriculture, though climate variability can cause water stress (Odekunle, 2004). The temperature averages between 25°C and 32°C, contributing to high evapotranspiration rates, which affect soil moisture retention and necessitate irrigation during the dry season (Adedokun *et al.*, 1989). The region is water-rich, with tributaries of the Niger River and the Anambra River, which support irrigation, fisheries, and domestic water use (Ezenwaji, *et al.*, 2016). The topography includes a mix of lowland plains and undulating terrains, with fertile alluvial soils along riverbanks that support diverse crops such as rice, cassava, maize, and vegetables. However, soil erosion and leaching are concerns in the region, requiring soil management practices (Igbokwe *et al.,* 2008).

Data Collection and Processing: The study utilized two datasets which includes the Geographical Information System (GIS) and climate dataset. The Geographical Information System (GIS) comprises the

Digital Elevation Model (DEM); this was sourced from the USGS, 30m resolution and was used for the terrain analysis, watershed delineation, and hydrological modeling. It was processed through conversion, projection (WGS 1984 UTM Zone 32N), resampling, and sink filling.

Satellite Imagery: The satellite imagery used was obtained from the Landsat 8 with a 30m resolution. It was used for land cover and vegetation analysis, with preprocessing steps including conversion, radiometric correction, NDVI and EVI calculation, and alignment.

Land Cover: the land cover was obtained from the USGS NLCD, with a 30m resolution: Processed for spatial alignment, resampling, and accuracy verification using satellite imagery and field observations. *Soil Type*: the soil type was sourced from the USDA SSURGO, with a 30m resolution. The soil type was processed through conversion, projection, resampling, and validation against field data for soil erosion modeling.

However, the climate Dataset which comprises the Rainfall Data was sourced from the Nigerian Meteorological Agency (NiMet). The rainfall data was processed into a raster format, re-projected, resampled, and validated against historical records for accuracy in hydrological modeling.

Development of flood Model: The flooding model was developed to predict flood susceptibility in Aguata Agricultural Zone. The comprehensive model was constructed following a systematic sequence of steps, including Modeling Framework, Algorithm Development, and implementation within a GIS environment as detailed below.

Modeling Framework: The modeling framework was based on established principles and equations from hydrological models such as the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) and the Soil and Water Assessment Tool (SWAT). These models are widely used for predicting flood risks and understanding runoff and water flow dynamics.

Algorithm Development and Testing: Algorithms were developed to automate the computation of critical parameters in the HEC-HMS and SWAT models. Python programming language was employed for spatial analysis and the development of raster-based processing algorithms for each flood-related factor.

Flood Modeling Parameters: The following parameters were calculated and integrated into the model: The R-Factor (Rainfall Intensity Factor) was calculated using rainfall data representing the volume and intensity of precipitation contributing to flooding, the SCS Curve Number (Soil Runoff Potential Factor) was derived from soil type and land use data to estimate runoff potential, the LS-Factor (Slope Length and Steepness Factor) was computed from the DEM, quantifying the impact of terrain on water flow and accumulation, the C-Factor (Vegetation Cover Factor) was based on vegetation indices such as NDVI and EVI, representing the effect of vegetation in reducing runoff, and the Drainage Density Factor was calculated using hydrological data to assess the efficiency of drainage networks in mitigating flooding.

The model implementation in the GIS environment involves using ArcGIS software, a robust platform for spatial analysis, raster processing, and hydrological modeling. A Python programming language was used for scripting, automating model workflows, and performing advanced computations. The raster layers representing each flood-related factor (R, SCS, LS, C, Drainage Density) were computed and combined to generate flood susceptibility maps. Also, the vector layers, such as watershed boundaries and stream networks, were integrated to enhance spatial analysis and visualization. Additionally, the factor maps were overlaid using GIS tools to compute the overall flood susceptibility map. This overlay approach allowed for a spatially explicit representation of risk areas. Hence, the GIS-based hydrological tools were employed to analyze flow direction and flow accumulation, identifying areas with concentrated runoff and potential flooding hotspots.

RESULTS AND DISCUSSION

A flood model, as well as the next ten years' prediction model was developed based on the effect of climate change in Aguata agricultural zones of Anambra State. Four (4) different results stages is presented and discussed, namely; the terrain analysis, the morphometric parameters, the hypsometric analysis, and the flood and flood prediction model.

Terrain analysis: The Digital Elevation Model (DEM): The terrain analysis of the Aguata Agricultural Zone was conducted using a Digital Elevation Model (DEM), which provided insights into elevation range, slope variations, and overall terrain patterns. The study revealed that the minimum elevation in the area is 50 meters, representing low-lying features such as valleys, plains, or gully erosion sites, while the maximum elevation reaches 236 meters, indicating the presence of hills, ridges, or elevated plateaus (Figure 2). The mean elevation was found to be 100.91 meters, suggesting a moderately elevated landscape, though it is slightly skewed by extreme values. The median elevation was recorded at 94 meters, slightly lower than the mean, indicating a terrain distribution with more land closer to lower elevations.

The elevation variation within the study area was calculated as 186 meters, suggesting moderate topographic relief characterized by rolling hills or foothills. The difference between the mean and median elevations reflects a positively skewed distribution, meaning that while much of the terrain is closer to the lower elevation levels, a few high points elevate the overall average. This terrain analysis is crucial for understanding factors such as erosion risks, water flow patterns, and agricultural suitability in the region.

Slope analysis: The slope analysis of the Aguata Agricultural Zone quantifies the steepness of the terrain, providing essential insights for hydrology, geomorphology, land use planning, and hazard assessment. The study revealed that the mean slope is 58.36 degrees, indicating a generally steep landscape typical of hilly or mountainous regions. However, the averaging process may obscure significant variations in slope across different areas.

The median slope, recorded at 63.43 degrees, suggests that half of the terrain is steeper than this value, while the other half is less steep as shown in Figure 3. Since the median is slightly higher than the mean, the slope distribution may be negatively skewed, with fewer gentle slopes affecting the average value. The standard deviation of 16.55 degrees reflects a moderate level of variability, indicating a mix of steep and gentle slopes within the study area. The high mean and median slope values suggest that the region is predominantly steep, which can influence factors such as accessibility, vegetation patterns, and water flow dynamics. The presence of steep slopes may also contribute to erosion and potential geomorphological changes, while gentler slopes are more likely to be found in valley floors or plateau-like areas.

Aspect Analysis: The aspect analysis of the Aguata Agricultural Zone examines the direction slopes face, which influences solar radiation exposure, microclimate variations, vegetation distribution, and land use suitability. The study found that the mean aspect of the terrain is 175.03°, indicating an overall southward slope orientation as shown in Figure 4. However, due to the circular nature of aspect data, the mean alone may not fully capture the distribution of slope directions. The median aspect of 180° confirms that at least half of the slopes in the study area face directly south, suggesting a predominant south-facing terrain orientation. A high standard deviation of 107.46° reflects significant variability in slope directions, indicating that slopes face multiple orientations rather than being concentrated in a single direction. This suggests a complex and rugged landscape with ridges, valleys, and irregular terrain features. The predominance of south-facing slopes has important implications for solar radiation exposure, potentially affecting microclimates, vegetation patterns, and hydrological processes such as snowmelt and water retention. However, the high variability in aspect values highlights the diverse nature of the terrain, where different slope directions contribute to a heterogeneous environmental and agricultural landscape.

Landform Analysis: Landform Analysis: The landform analysis of the Aguata Agricultural Zone classifies key geomorphological features, including valleys, hills, and plateaus, which impact hydrology, biodiversity, and land use planning. The study identified 2,694 valleys, 99,415 hills, and 1,029 plateaus as shown in Figure 5. The high hill count indicates a rugged, elevated landscape shaped by erosion and tectonic processes, while the lower valley and plateau counts suggest limited flat and low-lying areas. This terrain influences water flow, sediment transport, and habitat diversity. Hills create microclimatic variations, while valleys serve as drainage pathways, highlighting the region's complex geomorphological dynamics and environmental implications.

Curvature Statistics: The curvature analysis quantifies changes in slope and aspect, highlighting geomorphological processes like erosion and water flow. The study found a mean curvature of 0.0013, a median of 0.0, and a standard deviation of 1.69 as shown in Figure 6. A mean close to zero suggests a balanced terrain, while a slight positive value indicates rounded hilltops. The median of zero reflects an equal distribution of concave and convex areas, and the high standard deviation suggests significant variability. This indicates a dynamic landscape where convex areas may face erosion, while concave regions accumulate sediments, shaping the hydrological and geomorphological characteristics of the terrain.

Hillshade: The hillshade analysis simulates terrain illumination by calculating light interaction based on slope and aspect. The study found a mean hillshade value of 3.44 and a standard deviation of 158.56 (Figure 7). The low mean suggests most of the terrain is shadowed, likely due to steep slopes or unfavorable light alignment. The high standard deviation indicates a mix of bright and dark areas, reflecting a rugged landscape with sharp elevation changes. Shadowed areas may retain moisture longer, affecting drainage and vegetation. This highlights the terrain's complexity, where valleys and steep slopes create uneven light distribution and varied microclimatic conditions.

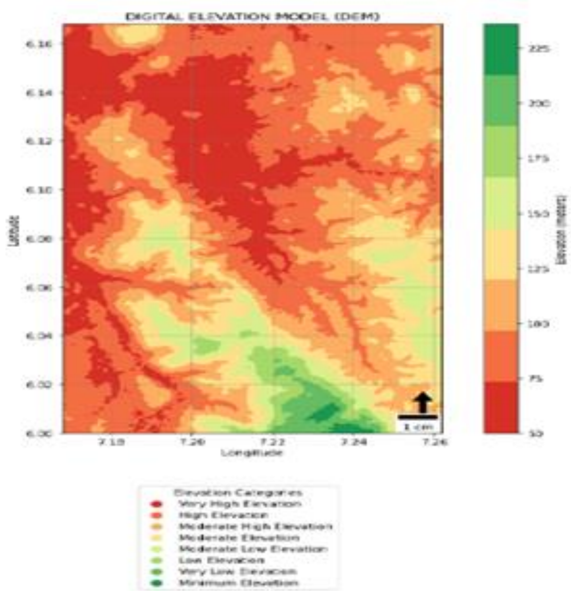

Fig. 2: The digital elevation model

Morphometric Parameters: The morphometric analysis quantifies the terrain's geometry and hydrological properties, highlighting its susceptibility to soil erosion, particularly under climate change. The study reveals a watershed area of 0.0086 m² with a high perimeter-to-area ratio, indicating an irregular shape that promotes uneven runoff distribution and localized erosion. A low circularity value of 0.0671 suggests an elongated watershed prone to increased flow velocity and concentrated erosion pathways. The high drainage density of 3600.0000 m^{-1}, and stream frequency of 115.8705 m^{-2} indicate an extensive stream network, leading to rapid runoff and heightened erosion risks.

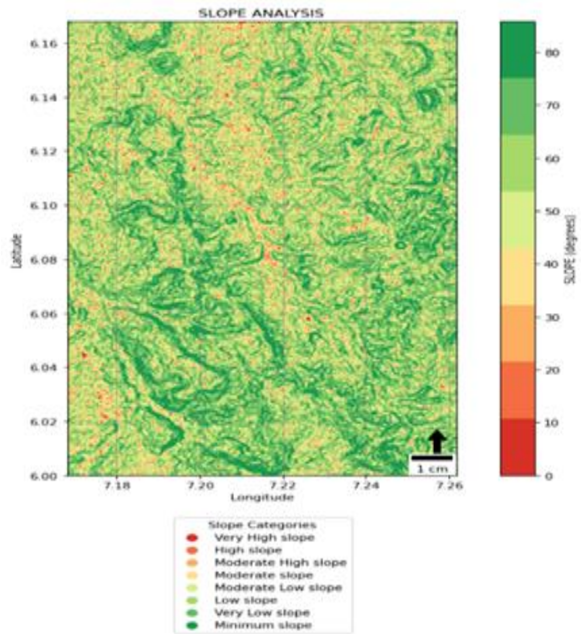

Fig 3: The slope analysis

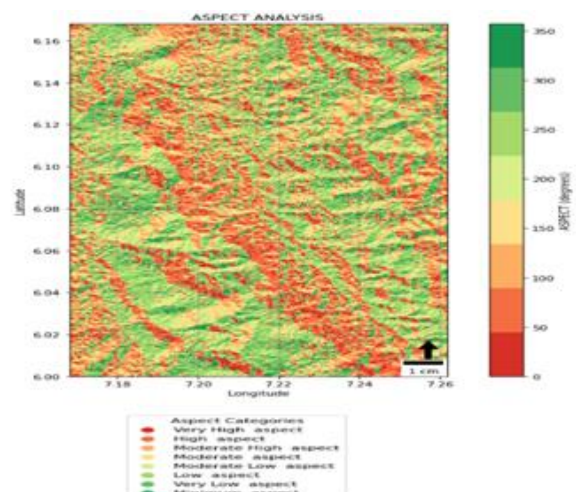

Fig 4: The study area aspect analysis

The compactness coefficient of 3.8598 and shape factor of 0.0053 confirm a highly elongated watershed, which enhances concentrated flow and erosion. The very high elongation ratio of 377.3733 further suggests rapid water movement, increasing erosion vulnerability, especially with intensifying rainfall due to climate change. High stream frequency implies continuous soil displacement, exacerbating land degradation. These characteristics suggest a fragile watershed with limited infiltration capacity, making it prone to severe erosion, land degradation, and soil fertility loss. To mitigate these effects, conservation practices such as contour farming, terracing, reforestation, and check dams are recommended. Managing the existing stream network and increasing vegetation cover will help reduce runoff speed and minimize soil erosion risks.

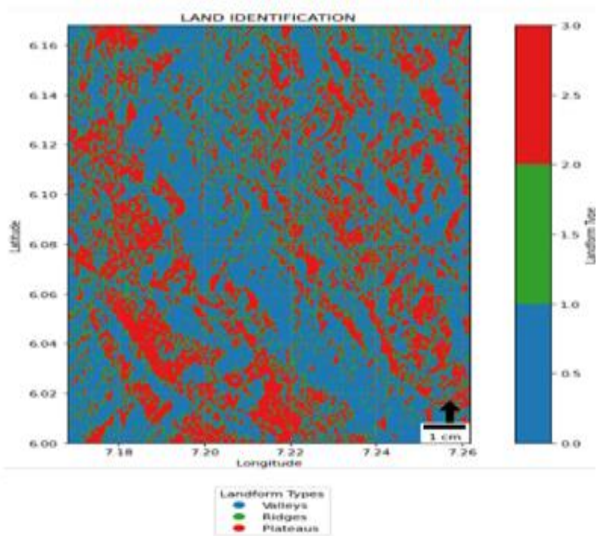

Fig 5: The landform analysis

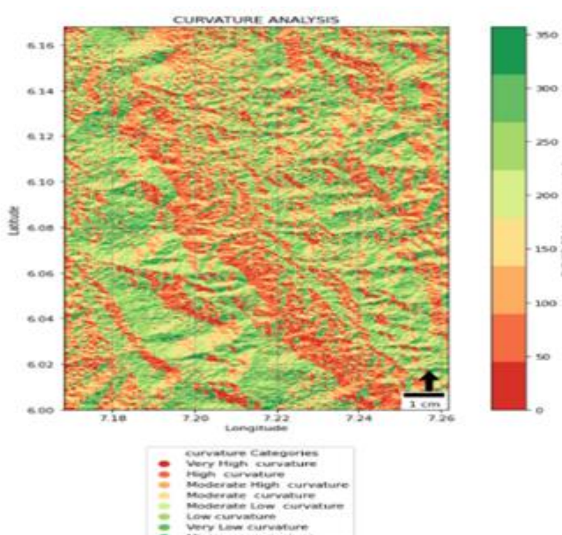

Fig 6: The curvature descriptive Analysis

Hypsometric Analysis: Hypsometric analysis assesses elevation distribution within a landscape, revealing its erosional stage and geomorphological characteristics. The study results show a hypsometric integral (HI) of 0.7403, mean elevation of 97.46 m, elevation range of 173.00 m, and relief of 173.00 m as shown in Figure 8. An HI of 0.7403 suggests a youthful erosional stage, with steep slopes and active geomorphic processes. This implies a high potential for erosion, particularly under increased rainfall due to climate change. The mean elevation of 97.46 m indicates a relatively low-lying area. Lower elevations can be prone to erosion if steep slopes exist within this range.

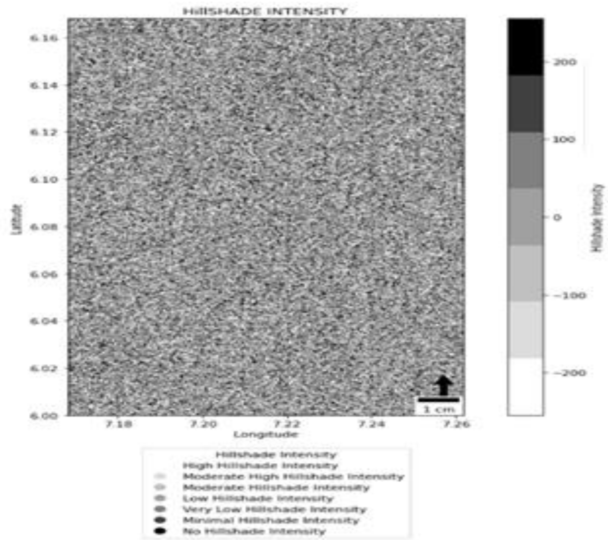

Fig 7: The curvature descriptive analysis

Additionally, low-lying areas are more susceptible to flooding, particularly during heavy rainfall events. While the elevation range of 173.00 m suggests moderate topographic variation, meaning both steep and flat areas exist. Steeper slopes are more prone to erosion, while flatter areas may experience sediment accumulation and water pooling. Increased rainfall can intensify these effects, leading to higher erosion in elevated areas and flooding in lower regions. However, a relief of 173.00 m indicates a mix of high and low elevations. Steep areas are vulnerable to erosion, while low-lying regions are at higher risk of flooding, particularly if the terrain lacks sufficient drainage infrastructure.

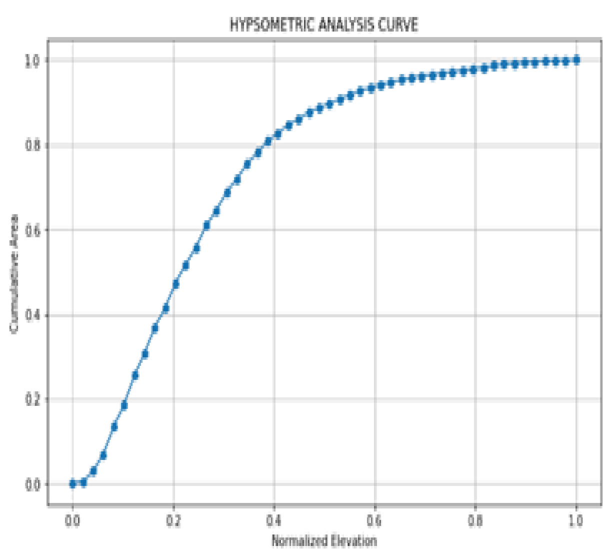

Fig 8: The hypsometric analysis curve of the study area

Flood Modeling: Water flow accumulation model: The flood modeling results reveals a significant water flow accumulation, with a total of 2,823,864.50 m² and an average of 13.81 m² as shown in Figure 9. These metrics are crucial in assessing water movement, erosion, and flooding risks. Areas with latitude and longitude above 6.6 show higher flow accumulation, indicating potential hotspots for soil erosion and gully formation. Climate change-driven intense rainfall increases runoff, leading to concentrated water flow and reduced infiltration, aligning with studies by Egboka and Okpoko (1984) and Obiefuna and Orazulike (2011). The well-developed runoff pathways suggest that topography and human activities, such as deforestation and land-use changes, influence water movement. Increasing rainfall intensity exacerbates soil degradation, affecting agricultural productivity. Areas with high flow accumulation are prone to waterlogging and severe flooding, threatening infrastructure and livelihoods. Reduced infiltration due to compacted or degraded soils further worsens flooding impacts, making effective flood and land management strategies essential.

Flood Risk Model: The flood risk analysis model highlights the Aguata Agricultural Zone's vulnerability to climate-induced disasters like soil erosion and flooding. With a mean flood risk of 10.98 mm and a total flood risk of 2,244,474.11 mm, the study reveals significant water accumulation and inundation potential (Figure 10). Climate change has intensified rainfall patterns, increasing flood risks. The mean flood risk suggests potential waterlogging, nutrient leaching, and soil destabilization, while the total flood risk indicates large-scale inundation. Heavy rainfall accelerates soil erosion by increasing runoff and topsoil destabilization, leading to gully formation and land fragmentation. Higher runoff volumes transport sediment, reducing soil fertility and agricultural productivity. Persistent flooding disrupts farming activities, damages crops, and threatens infrastructure and settlements, particularly in low-lying areas. These findings emphasize the need for effective flood management and erosion control strategies to protect agricultural land, infrastructure, and livelihoods in the region.

Next 10-Year Predicted Flood Risk Model: The 10-year flood risk prediction for Aguata Agricultural Zone reveals a significant increase in flood hazards due to climate change. Figure 11 shows that the future mean flood risk of 22.12 mm and total flood risk of 4,523,622.06 mm represent a 101.46% and 101.54% increase, respectively, indicating intensified flood events and prolonged inundation. This surge in flood depth and volume will accelerate surface runoff, leading to severe soil erosion, topsoil loss, and reduced agricultural productivity. Steeper slopes and high-flow accumulation areas face heightened risks of gully formation and sediment displacement. Increased flooding threatens farmlands, infrastructure, and settlements, disrupting transportation and escalating recovery costs. Additionally, flood-prone zones may expand, affecting previously unaffected areas and demanding urgent mitigation efforts. Proactive planning is essential to manage these risks and protect livelihoods, emphasizing the need for adaptive flood management strategies to counter the growing impacts of climate variability in the region.

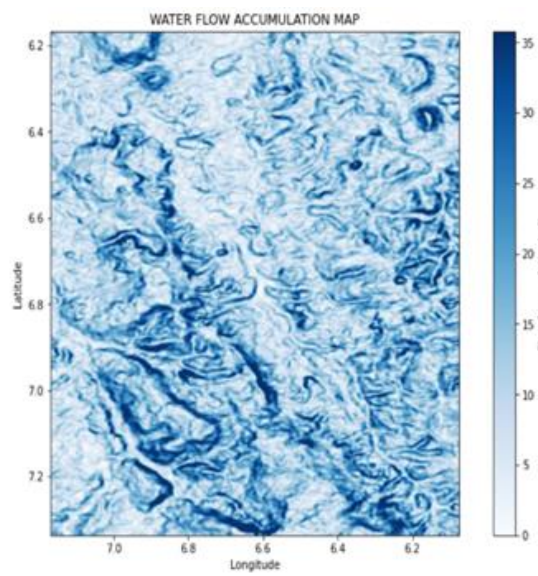

Fig 9: The flood accumulation map model

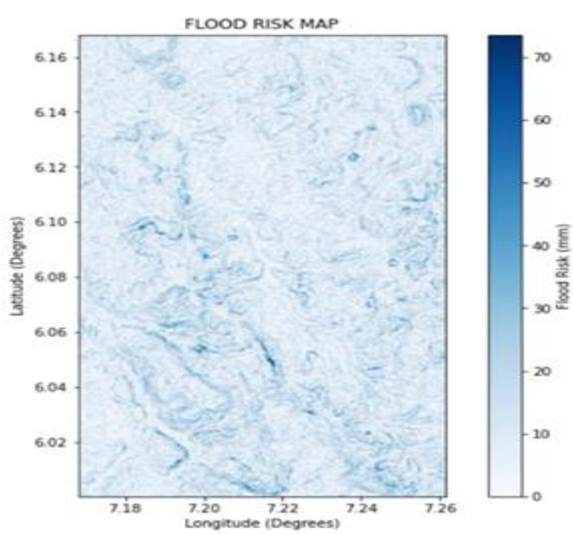

Fig 10: The flood risk map model

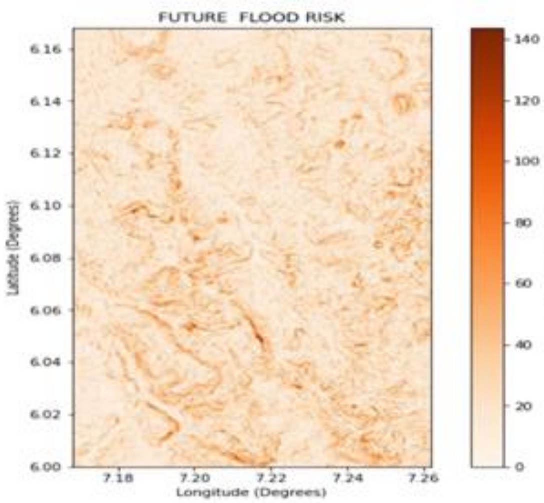

Fig 11: A ten year predicted flood model Model

Sensitivity of flood risk to rainfall intensity: The sensitivity of flood risk to rainfall intensity in the Aguata Agricultural Zone highlights the impact of climate change on hydrological hazards. As shown in Figure 12, increased rainfall intensity leads to higher flood risks and soil erosion, threatening agriculture, infrastructure, and communities.

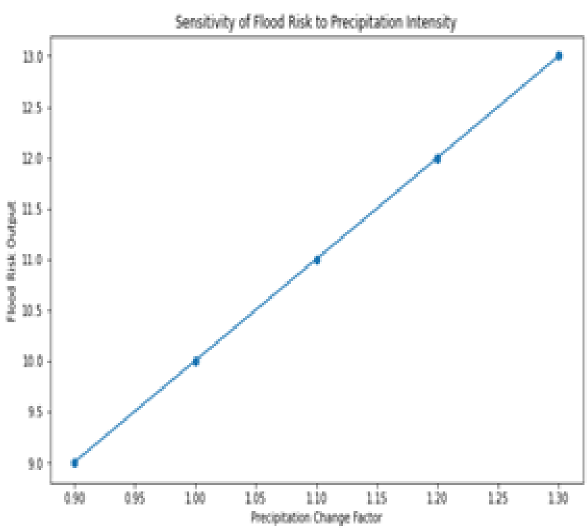

Fig 12: The sensitivity of flood risk to rainfall intensity

When rainfall exceeds the soil's infiltration capacity, surface runoff increases, accumulating in low-lying areas and causing deeper, more widespread flooding. In Aguata, soil types and land use constraints further elevate flood risks. Intense rainfall also generates powerful runoff, detaching soil particles, deepening gullies, and accelerating erosion. Sediment-laden floodwaters contribute to siltation in downstream water bodies, reducing their capacity to handle future runoff. Repeated exposure to heavy rainfall compacts soil, decreases permeability, and increases runoff severity. Additionally, vegetation loss from flooding weakens the land's ability to absorb water, perpetuating a cycle of rising flood vulnerability. Effective mitigation strategies are essential to manage these escalating risks.

Conclusion: The study highlights the significant impact of climate change on flooding in the Aguata Agricultural Zone, emphasizing increased flood risks due to changing rainfall patterns and topographical factors. GIS-based modeling provided insights into terrain characteristics, hydrological dynamics, and future flood susceptibility, revealing a projected rise in flood risk over the next decade. Findings indicate that intensified rainfall will exacerbate erosion, soil degradation, and agricultural losses, threatening local livelihoods. Effective flood management strategies, including improved drainage, afforestation, and soil conservation, are crucial for mitigating these impacts. The study underscores the importance of climate adaptation policies to enhance agricultural resilience and sustainability in the region. Future research should refine predictive models and explore community-based adaptation measures for long-term flood mitigation.

Declaration of Conflict of Interest: The authors declare no conflict of interest (if none).

Data Availability Statement: Data are available upon request from the first author or corresponding author or any of the other authors

REFERENCES

Adedokun, JA; Emofurieta, WO; Adegoke, OS (1989). The composition of harmattan dust in Nigeria: Its characteristics and metal content. *J. Eart. Surf. Pro. and Land*. 14(6), 615–625.

Borrelli, PR; Panagos, DA; Lugato, P; Yang, E; Alewell, JE; Ballabio, C (2020). Land use and climate change impacts on global soil erosion by water (2015-2070). *Proc. Nat. Acad. Sci.* 117(36), 21994-22001.

Egboka, BCE; Okpoko, EI (1984). Gully erosion in the Agulu-Nanka region of Anambra State, Nigeria. Challenges and solutions. *J. Environ. Geo.* 6(3), 165-170.

Ezenwaji, EE; Phil-Eze, PO; Igbokwe, JI (2016). Water supply problems in the rural communities of the Aguata region of Anambra State, Nigeria. *J. Wat. Res. Prot.* 8(3), 314-325.

Igbokwe, JI; Akinyede, JO; Dang, B; Ono, MN; Nnodu, VC; Anike, LO (2008). Mapping and monitoring of the impact of gully erosion in Southeastern Nigeria with satellite remote sensing and Geographic Information System. *Inter. Arch. Photo. Rem' Sens. Spat. Info. Sci.* 37, 865-871.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report. *Intergov. Pan. Clim. Chan. Gene. Swit.* 2014.

Kirkby, MJ; Jones, RJA; Irvine, B; Gobin, A; Govers, G; Cerdan, O; Grimm, M (2004). Pan-European soil erosion risk assessment: *Pese. Ma.* Ispr. 73, 1-30.

Lal, R (2001). Soil degradation by erosion. *Lan. Deg. Dev.* 12(6), 519-539.

Montgomery, DR (2007). Soil erosion and agricultural sustainability. *Proce. Nat. Acad. Sci.* 104(33), 13268-13272.

Nearing, MA; Pruski, FF; O'Neal, MR (2005). Expected climate change impacts on soil erosion rates: A review. *J. Soi. Wat. Cons.* 60(1), 43-50.

Odekunle, TO (2004). Rainfall and the length of the growing season in Nigeria. *Inter. J. Clim.* 24(4), 467-479.

Ofomata, GEK (1985). Soil erosion in Nigeria: The views of a geomorphologist. *Uni. Nig. Pre.*

Ogunbodede, BA; Olaniyan, O; Adeleye, O (2022). Climate change and land degradation in Nigeria: Challenges and mitigation strategies. *Env. Man. Pol.* 36(2), 235-249.

Okpala-Okaka, C; Ogbu, C (2019). Climate change and food security in Nigeria: Implications for policy and adaptation strategies. *Niger. J. Environ. Sci.* 3(1), 72-84

Pimentel, D; Kounang, N (1998). Ecology of soil erosion in ecosystems. *J. Ecosy.* 1(5), 416-426.

Wischmeier, WH; Smith, DD (1978). Predicting rainfall erosion losses: A guide to conservation planning. *U.S. Depart. Agric. Agric. Handb*. No. 537.