

An Integrated Geospatial and Socio-economic Assessment of Flood Risk in North-western Nigeria Using Multi-Criteria Decision Analysis

MUSA MUHAMMAD CHINDO¹, ASADULLAH MUHAMMAD^{2,3}

¹*Department of Survey & Geoinformatics, Federal Polytechnic Nasarawa, Nasarawa 962101, Nigeria.*

²*Nigeria Customs Service, Plateau/Benue/Nasarawa Command.*

³*Department of History and International Relations, Federal University Lafia, Nigeria.*

Abstract- *Flood disasters have become increasingly frequent and severe in Nigeria, driven by a combination of climatic shifts and anthropogenic pressures. This research paper assesses flood risk vulnerability across the seven states of the Northwest geopolitical zone (Sokoto, Kebbi, Zamfara, Katsina, Kano, Jigawa, and Kaduna). Utilising a Multi-Criteria Decision Analysis (MCDA) framework integrated with Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP), the study evaluates physical hazards—such as elevation, slope, and drainage density—alongside the vulnerability of the population determined by their exposure. The findings indicate that Kebbi and Sokoto have the highest flood hazard, largely due to their low-lying floodplains and proximity to major rivers. When exposure and socioeconomic vulnerability are considered, 27.75% of the region is classified as having very high flood risk, primarily across nine LGAs in Kebbi, two in Zamfara, and one in Sokoto. High flood risk is concentrated mainly in Kebbi (15 LGAs), Sokoto (19 LGAs), Kano (4 LGAs), and Jigawa (3 LGAs).*

I. INTRODUCTION

Flooding remains one of the most widespread and destructive natural hazards in Nigeria (Komolafe et al., 2015), with far-reaching consequences for human lives, livelihoods, infrastructure, food production, and regional development. Each year, flooding affects communities across the country through the destruction of homes, roads, bridges, schools, health facilities, and agricultural land, while also disrupting local economies and displacing vulnerable populations. Although national attention has often focused on the coastal and southern regions because of their exposure to coastal inundation and intense rainfall, North-western Nigeria has increasingly

emerged as an important flood-risk corridor (Bello et al., 2022). The region experiences both fluvial flooding, associated with the overflow of rivers and drainage networks, and pluvial flooding, which occurs when intense rainfall exceeds the capacity of local drainage systems and produces rapid surface runoff and flash flooding. North-western Nigeria encompasses extensive areas of the Sudan and Sahel savannah ecological zones, where climatic variability, high temperatures, seasonal rainfall, and increasing pressure on land and water resources interact to shape flood vulnerability.

The impacts of climate change are further complicating these conditions by contributing to changes in rainfall intensity, duration, and distribution and increasing the likelihood of extreme weather events. At the same time, rapid population growth, urban expansion, inadequate drainage infrastructure, changes in land use and land cover, and the degradation of natural drainage systems can increase the exposure of communities to flooding. Consequently, flood risk in the region is not determined by rainfall or river discharge alone but emerges from the interaction between hazard, exposure, and social and environmental vulnerability. The consequences of recurrent flooding have become particularly evident during major flood events in recent decades. The floods of 2012 and 2022 caused extensive damage across several parts of North-western Nigeria, affecting settlements, agricultural land, transportation networks, and essential services (Abu-hanifa et al., 2025; Tudunwada & Ahmad, 2026).

In Kebbi State, for example, flooding has repeatedly affected extensive agricultural areas, posing a serious threat to rice production and rural livelihoods. Kebbi is widely recognised as one of Nigeria's major rice-producing regions, meaning that flood-related agricultural losses can extend beyond individual households to affect food supply chains and national food security. Similarly, severe flooding in Jigawa and Sokoto states has resulted in widespread displacement, damage to homes and infrastructure, and disruption of agricultural activities and local livelihoods. The vulnerability of North-western Nigeria is therefore shaped by a combination of environmental and socioeconomic factors. Rural communities whose livelihoods depend heavily on agriculture are particularly sensitive to disruptions caused by flooding, while rapidly growing urban settlements may face additional risks associated with inadequate drainage, impermeable surfaces, informal development, and encroachment on flood-prone areas. Limited access to resilient infrastructure, emergency services, financial resources, and effective early-warning systems can further constrain the capacity of communities to prepare for, respond to, and recover from flood events. These interacting factors create considerable spatial variation in flood vulnerability, even among communities exposed to similar levels of rainfall or river flooding. Understanding this spatial variation is essential for developing effective flood-risk reduction strategies. Identifying areas where high flood hazards coincide with highly exposed populations, vulnerable livelihoods, and limited adaptive capacity can help policymakers and practitioners prioritise investments in drainage infrastructure, flood protection, early-warning systems, emergency preparedness, climate-resilient agriculture, and community-based adaptation. Such assessments are particularly important in North-western Nigeria, where recurrent flooding intersects with agricultural dependence, poverty, rapid environmental change, and broader pressures associated with climate variability.

Consequently, assessing flood vulnerability in North-western Nigeria is not simply an environmental exercise; it is closely connected to food security, livelihood protection, public health, infrastructure resilience, and regional stability. A spatially explicit

understanding of flood vulnerability can provide an evidence base for targeted interventions and support more effective allocation of limited resources. It can also contribute to broader efforts to strengthen climate resilience and sustainable development in vulnerable communities, particularly as Nigeria seeks to address the growing challenges posed by climate change and increasingly frequent extreme weather events. Despite the recurring and often severe nature of flooding in North-western Nigeria, disaster management in the region remains predominantly reactive, with interventions frequently occurring after communities and infrastructure have already been affected. This approach is further constrained by the limited availability of integrated flood-vulnerability assessments that consider both the physical characteristics of the environment and the socio-economic conditions that shape people's ability to prepare for, respond to, and recover from flooding.

While previous studies have provided valuable insights into flood hazards and vulnerability, many have focused on individual states, selected communities, or specific river basins. Consequently, there remains a gap in understanding the spatial pattern of flood vulnerability across North-western Nigeria as a wider region. The situation is becoming increasingly complex as rapid urbanisation, population growth, and the expansion of informal settlements continue to increase human exposure to flood hazards. In many urban and peri-urban areas, settlements have expanded into floodplains and other environmentally sensitive locations where access to adequate drainage and protective infrastructure is limited. At the same time, high levels of poverty, unemployment, and dependence on climate-sensitive livelihoods can reduce household and community capacity to prepare for and recover from flood events. These interacting environmental and socio-economic pressures mean that flood impacts are unlikely to be determined solely by physical exposure. A more comprehensive assessment is therefore needed to identify areas where environmental susceptibility coincides with high population exposure and limited adaptive capacity. Such an integrated vulnerability framework can provide a stronger evidence base for targeted preparedness, risk reduction, land-use

planning, and more proactive disaster-management strategies across North-western Nigeria.

This paper therefore assesses flood risk in North-western Nigeria by integrating physical hazard, exposure and socio-economic vulnerability. The specific objectives are to: (i) identify the physical drivers of flood hazard in the region with geospatial parameters; (ii) map the exposure of population and assets to flood hazard; (iii) construct a socio-economic vulnerability index from indicators of sensitivity and adaptive capacity; (iv) combine these components into an integrated flood risk map through Multi-Criteria Decision Analysis (MCDA); and (v) validate the resulting map against observed flood events.

II. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1. GIS-based multi-criteria flood susceptibility mapping

Assessing flood risk and adaptation strategies in Hadejia River Basin in Northwest Nigeria using Multi-Criteria Decision Analysis (MCDA) to identify and map areas with different levels of flood risk, (Muhammad et al., 2026) investigates how changes in land use and land cover influence flood occurrence and distribution, with particular attention to the relationship between human activities, environmental changes, and flood dynamics. They provided a basis for understanding flood susceptibility and supporting risk management. The research also explores how rural communities respond to flooding, focusing on the adaptation strategies they adopt, the effectiveness of local interventions, and their capacity to cope with flood-related impacts. The study uses data collected through a three-phase field reconnaissance survey conducted between August 2023 and January 2024, drawing on both primary and secondary sources. The data included satellite imagery, GPS coordinates, and topographic maps to assess flood risk and adaptation strategies in Hadejia River Basin in Northwest Nigeria using Multi-Criteria Decision Analysis (MCDA) to identify and map areas with different levels of flood risk.

Muhammad et al. (2026) investigate how changes in land use and land cover influence flood occurrence

and distribution, with particular attention to the relationship between human activities, environmental changes, and flood dynamics. They provided a basis for understanding flood susceptibility and supporting risk management. The research also explores how rural communities respond to flooding, focusing on the adaptation strategies they adopt, the effectiveness of local interventions, and their capacity to cope with flood-related impacts. The study uses data collected through a three-phase field reconnaissance survey conducted between August 2023 and January 2024, drawing on both primary and secondary sources. The data included satellite imagery, GPS coordinates, topographic and soil maps, hydrological records, and historical rainfall information.

In the study, Image pre-processing, classification, and MCDA techniques were used to analyse the contributing factors and produce flood-risk maps. The findings of the study revealed considerable variation in flood susceptibility across the study area. Approximately 46.54% of the area was classified as very low risk, while 19.86% fell within the low-risk category. Moderate-risk zones accounted for 18.60% of the area, indicating the need for improved land-use planning and targeted mitigation measures. High-risk areas covered 11.23% of the study area and were identified as particularly susceptible to flooding, requiring substantial risk-reduction interventions. The remaining 3.76% was classified as very high risk, highlighting locations where urgent attention, preparedness, and emergency planning may be necessary.

Overall, the study demonstrates the value of integrating land-use and land-cover analysis with MCDA to identify flood-prone areas and inform community-level flood management and adaptation planning, topographic and soil maps, hydrological records, and historical rainfall information. Image pre-processing, classification, and MCDA techniques were used to analyse the contributing factors and produce flood-risk maps. The findings of the study revealed considerable variation in flood susceptibility across the study area. Approximately 46.54% of the area was classified as very low risk, while 19.86% fell within the low-risk category. Moderate-risk zones accounted for 18.60% of the area, indicating the need

for improved land-use planning and targeted mitigation measures. High-risk areas covered 11.23% of the study area and were identified as particularly susceptible to flooding, requiring substantial risk-reduction interventions. The remaining 3.76% was classified as very high risk, highlighting locations where urgent attention, preparedness, and emergency planning may be necessary. Overall, the study demonstrates the value of integrating land-use and land-cover analysis with MCDA to identify flood-prone areas and inform community-level flood management and adaptation planning.

Focusing on Multi-hazard risk and integrating hazard, exposure, and vulnerability indicators (Nnah & Ikwueze, 2025) provided a GIS-based assessment of the combined risks associated with flooding, soil erosion, and desertification in the Sudano-Sahelian region of North-western Nigeria. The research offers insight into the spatial distribution of environmental risks and identifies communities and areas that may require priority attention. The use of multiple datasets, including vegetation indices, population distribution, settlement density, soil characteristics, and topographical factors, provides a broad basis for understanding the factors contributing to these hazards. One of the key strengths of the study is its consideration of multiple environmental hazards within a single analytical framework. The findings indicate that flood risk is particularly pronounced in low-lying areas, while erosion is associated with soil and slope characteristics, and desertification is linked to vegetation loss.

The identification of areas experiencing high and very high multi-hazard risk in the study highlights the potential for these hazards to overlap and intensify the challenges faced by local communities. The study also recognises that risk is influenced not only by the severity of environmental hazards but also by population concentration, settlement patterns, and economic activity. The research has practical relevance for environmental management, disaster risk reduction, and regional development planning. Its recommendations, including drainage rehabilitation, afforestation, land-use planning, and early warning systems, provide a basis for developing strategies to reduce vulnerability and strengthen community

resilience. However, the abstract could be improved by briefly explaining how the weights for the different indicators were determined and whether the resulting risk maps were validated.

Clarifying the distinction between hazard, susceptibility, exposure, and overall risk would also strengthen the methodological presentation. In addition, the geographical scope should be stated consistently, and the reported area percentages should be clearly linked to the total study area. Overall, the study makes a useful contribution to understanding the spatial patterns of multiple environmental hazards in North-western Nigeria. Its integrated GIS approach can support the identification of high-risk locations and inform targeted planning and mitigation efforts. The findings underline the importance of considering interacting environmental hazards alongside the social and economic conditions that influence their impacts. Examining flood susceptibility in Jigawa State, Nigeria, by identifying and mapping areas that are vulnerable to flooding, Idris et al., 2025) highlighted the importance of understanding spatial variations in flood risk to support effective disaster preparedness and planning. The researchers employed a combination of Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP), a multi-criteria decision-making technique, to assess flood susceptibility using eight factors: distance to rivers, elevation, flow accumulation, lineament density, slope, geology, soil type, and land use and land cover. The findings indicate that distance to rivers was the most influential factor in determining flood susceptibility, followed by elevation, flow accumulation, lineament density, land use and land cover, slope, geology, and soil type. The resulting susceptibility map showed that 27.68% of the study area was classified as having very high flood susceptibility, while 29.20% fell within the high-susceptibility category. Together, these areas accounted for 56.88% of the state, with 12 of the 23 Local Government Areas falling within these two categories. The study demonstrates how integrating GIS with AHP can support the spatial assessment of flood-prone areas. It also emphasises the importance of establishing effective early warning systems to strengthen preparedness and reduce the potential impacts of future flood events.

Despite these studies on flood vulnerability in the Northwest, most of the studies focused on individual states, local communities, or specific river basins, with many concentrating primarily on the physical characteristics of flood hazards. Although these studies have contributed to understanding flood-prone areas, they may not fully capture how flood hazards interact with population exposure and socioeconomic vulnerability across broader regions. This highlights the need for a more integrated approach that considers these interconnected dimensions. This study therefore addresses this gap by examining flood hazard, exposure, and socioeconomic vulnerability across all seven states of northwestern Nigeria, providing a broader regional perspective that can support more comprehensive flood risk assessment and planning.

2.2. Conceptual Framework

This study is based on the risk framework of the Intergovernmental Panel on Climate Change (Field, 2014), which has three components: hazard, exposure and vulnerability. Hazard refers to the physical climate-related event or process that has the potential to cause harm. In this study, hazards may include events such as extreme rainfall, river overflow,

flooding, or other climate-related processes that can adversely affect people, infrastructure, and the environment. Exposure refers to the presence of people, livelihoods, infrastructure, services, and other assets in locations that may be adversely affected by a hazard. Exposure therefore reflects what is located in harm's way and the spatial distribution of potentially affected populations and assets. Vulnerability is the propensity or predisposition of individuals, communities, systems, or assets to be adversely affected when exposed to a hazard. It is influenced by a range of social, economic, demographic, physical, and institutional factors, including socioeconomic deprivation, access to resources and services, housing conditions, health status, and the capacity of institutions and communities to prepare for, respond to, and recover from hazardous events. Within this framework, risk is therefore not determined by the hazard alone. A severe hazard may produce relatively limited impacts where exposure and vulnerability are low, whereas the same hazard can result in substantial impacts where large populations or valuable assets are exposed.

Table 1. Operationalisation of the hazard–exposure–vulnerability framework

Component	Meaning in this study	Measured by	Output
Hazard (H)	Physical likelihood of flooding	Elevation, slope, rainfall, distance to rivers, soil permeability, land use/land cover	Flood hazard index (0–1)
Exposure (E)	People and assets located in areas that can flood	Population density, built-up area, cropland	Exposure index (0–1)
Vulnerability (V): sensitivity	Socio-economic conditions that increase harm	Poverty, farming dependence, housing quality, dependency ratio	Sensitivity sub-index (0–1)
Vulnerability (V): adaptive capacity	Ability to prepare, respond and recover	Literacy, access to health care, road access, access to warning channels	Adaptive capacity sub-index (0–1)
Risk (R)	Expected severity of flood impact	$R = H \times E \times V$	Integrated flood risk index (0–1)

III. METHODOLOGY

3.1. Study Area

The study covers the states of Sokoto, Kebbi, Zamfara, Katsina, Kano, Jigawa, and Kaduna (Figure 1). The region is predominantly flat to undulating, with the Jos Plateau influencing the hydrology of the southern fringe. Major river systems include the Sokoto-Rima, Hadejia-Jama'are, and the Kaduna River (Figure 2) (Ibrahim et al., 2022). As is typical of West Africa, the climate of North-western Nigeria is primarily shaped by the interaction of two contrasting air masses. The first is the tropical continental air mass, which is dry and often carries dust from the Sahara Desert.

The second is the tropical maritime air mass, which develops over the Atlantic Ocean and brings warm, moisture-laden air into the region. The relative influence of these air masses varies according to the seasonal movement of the Inter-Tropical Convergence Zone (ITCZ), which marks the broad boundary between the continental and maritime airflows. The seasonal interaction between these air masses produces the characteristic wet and dry seasons

experienced across much of West Africa. The tropical maritime air mass is primarily responsible for the rainy season, whereas the dominance of the tropical continental air mass during the dry season results in drier atmospheric conditions. Rainfall generally becomes less frequent and less intense with increasing distance from the Atlantic coast toward the northern parts of the region.

Much of the annual precipitation is generated by convective thunderstorms, particularly those associated with organised disturbance systems known as squall lines. These systems are especially common during the main rainy season, from approximately June to September, and have historically accounted for a substantial proportion of annual rainfall across many parts of West Africa (Adefolalu, 1986). The region comprising Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto and Zamfara state covers approximately 424,700 km² (Office of the Surveyor-General of the Federation) and has an estimated population of 41 million (Abdussalam et al., 2014).

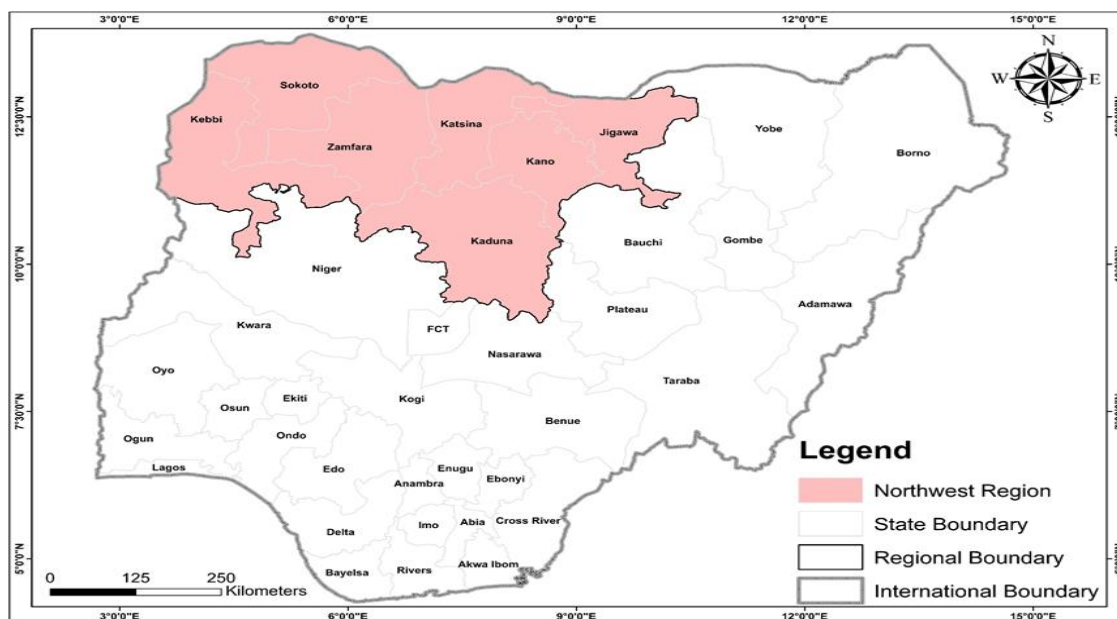


Figure 1. North-western Nigeria: study area

3.2. Data Sources

The data are grouped into four categories: physical data for the hazard index, exposure data, and

vulnerability index (Table 1). All raster layers were projected to Africa Albers Equal Area Conic because the study area cuts across WGS 84 / UTM zone 31N

or 32N and were resampled to a common 30 m grid.
Continuous data were resampled with bilinear

interpolation, and categorical data with nearest-neighbour assignment.

Table 1. Data sources

Category	Dataset	Variable(s)	Resolution / unit	Period	Source
Physical	SRTM DEM	Elevation, slope	30 m	2000	NASA/USGS (Error! Reference source not found.)
Physical	CHIRPS v2.0	Mean annual rainfall r maximum 1-day rainfall	0.05° (~5.5 km)	1981–2024	Climate Hazards Center (Error! Reference source not found.)
Physical	Soil product	Clay and sand content	30 arc-seconds	2023	FAO (Error! Reference source not found. and Error! Reference source not found.)
Physical	River network.	Distance to rivers	-	-	HydroSHEDS (Error! Reference source not found.)
Physical	ESA WorldCover	Land use/land cover	10 m	2020	European Space Agency (Error! Reference source not found.)
Exposure	WorldPop or GPW v4	Population density	100 m / 1 km	2025	NASA

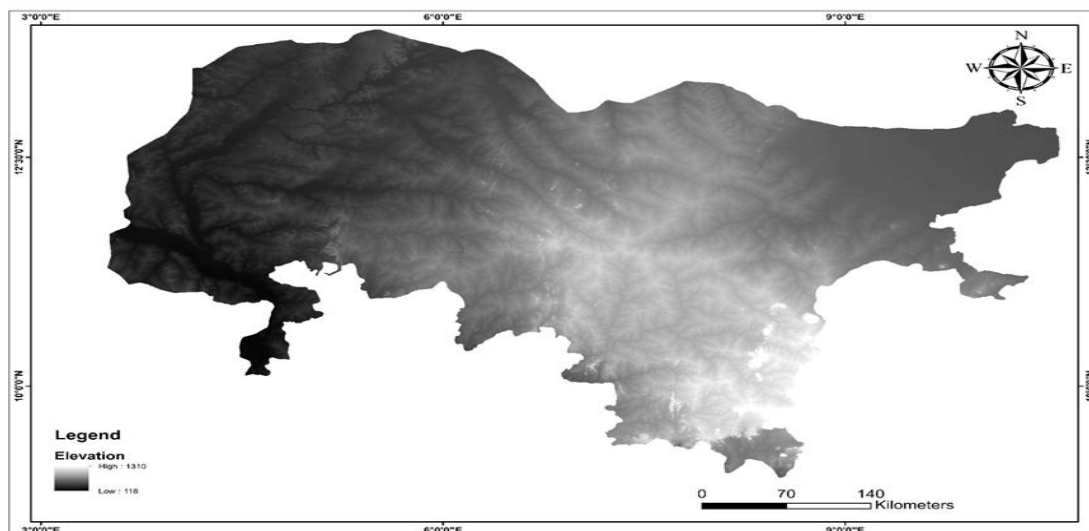


Figure 2. Digital elevation model of North-western Nigeria

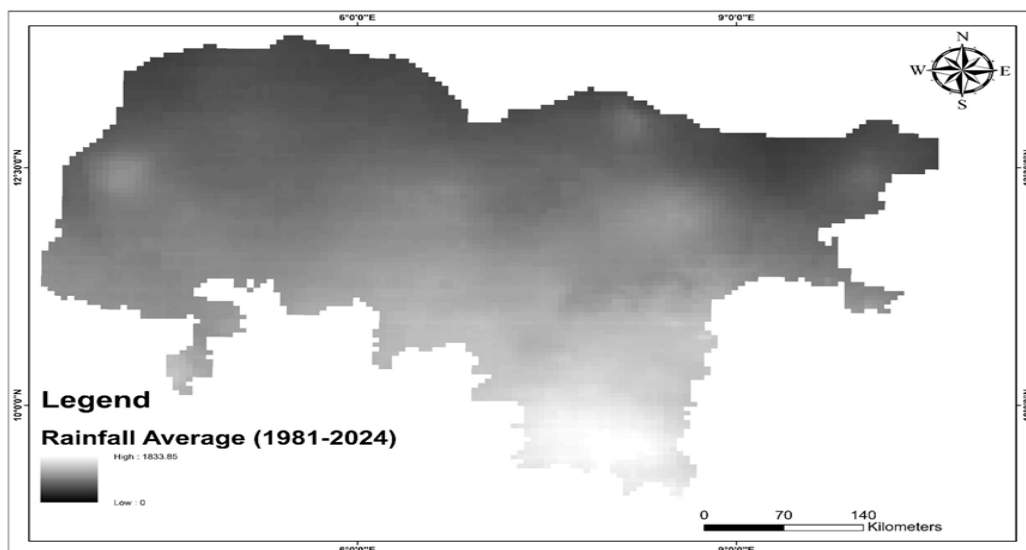


Figure 3. Mean annual CHIRPS rainfall (1981–2024) of North-western Nigeria

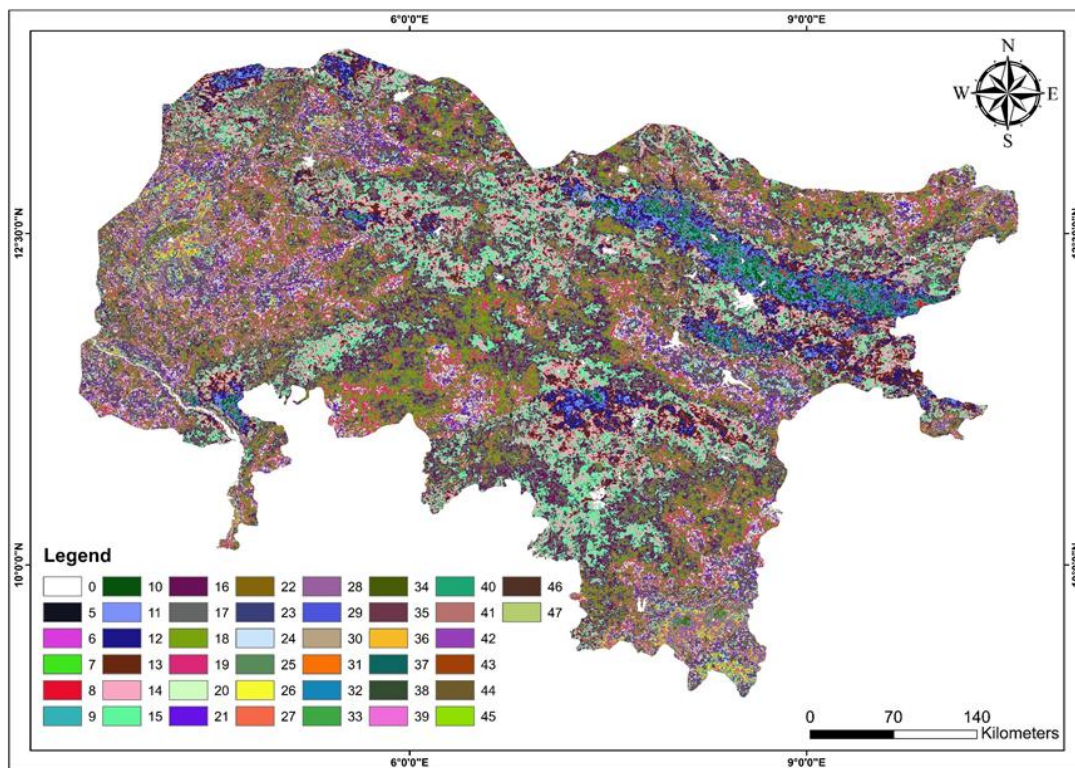


Figure 4. Soil clay content of North-western Nigeria

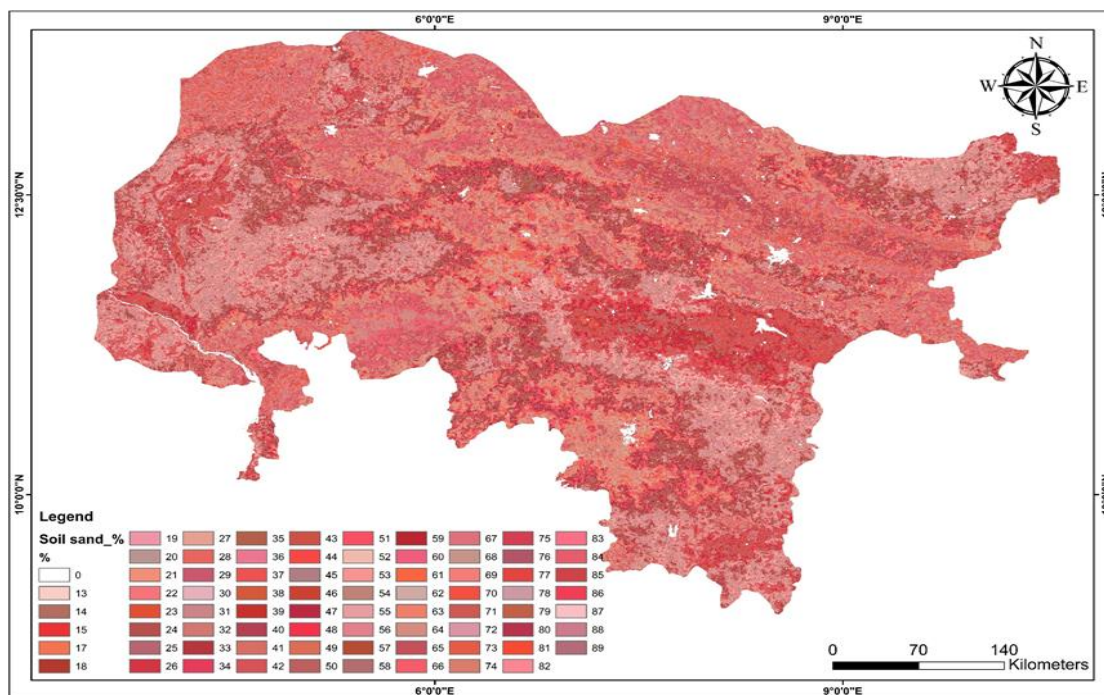


Figure 5. Soil sand content of North-western Nigeria

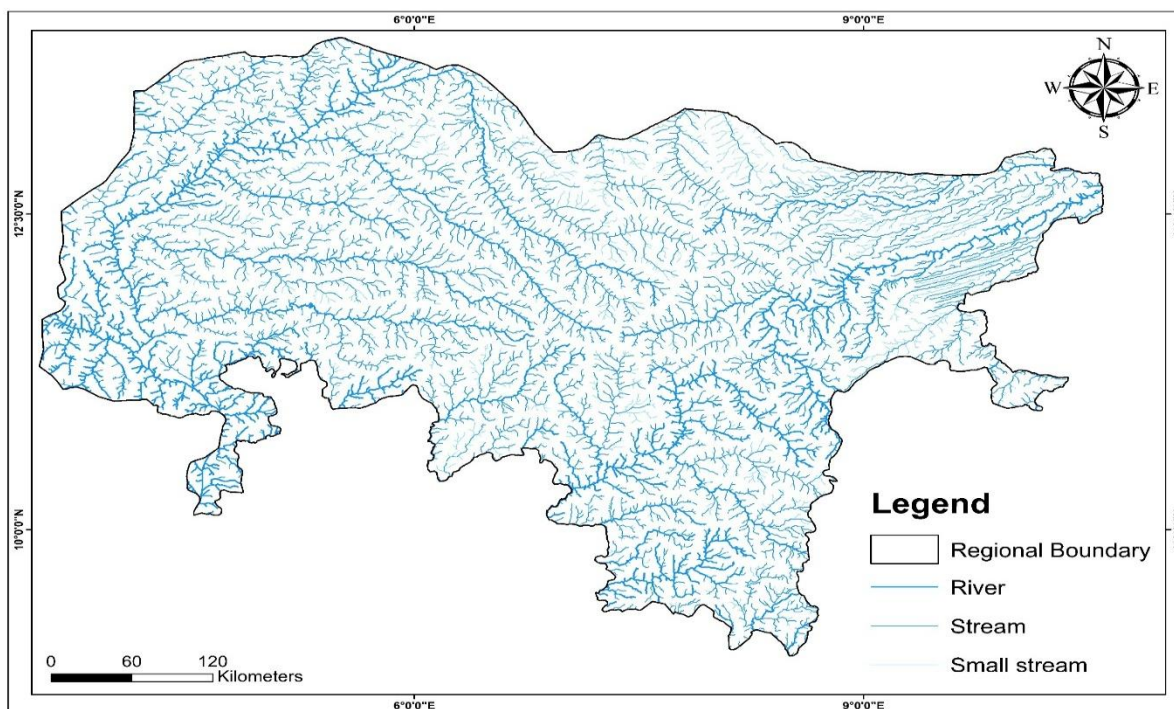


Figure 6. Surface water of Northwest Nigeria

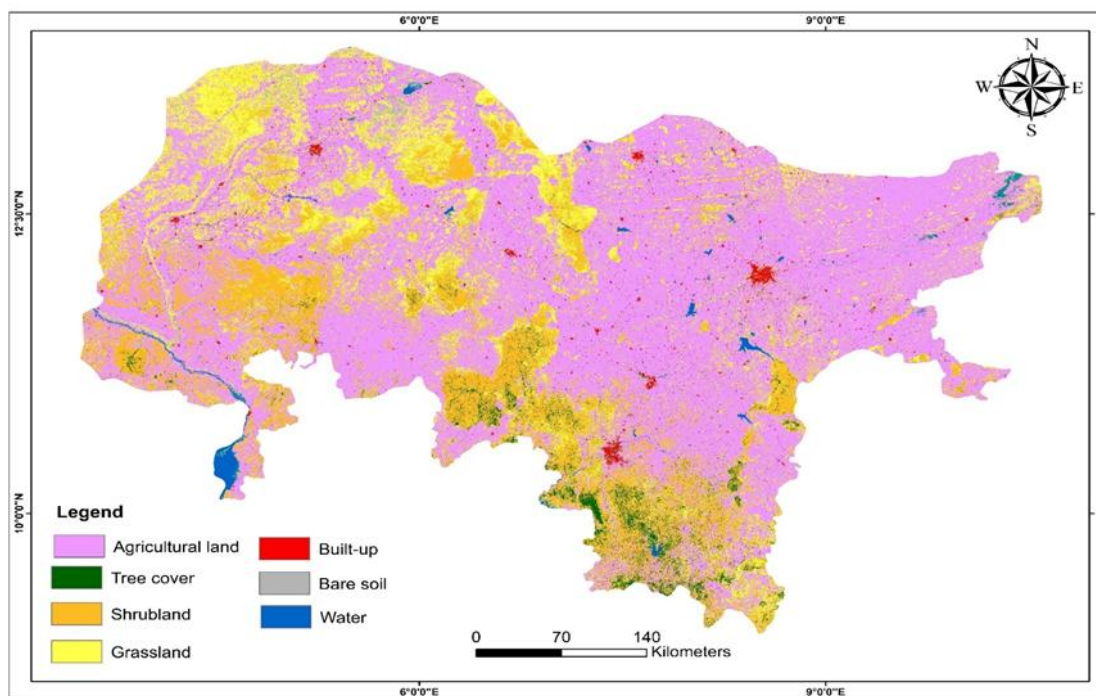


Figure 7. Land use/land cover of North-western Nigeria

3.3. Flood Hazard Index Mapping

Six physical factors were used to calculate the flood hazard index. Each factor was reclassified into five classes and given a rating from 1 (very low) to 5 (very

high), as shown in Table 3. The soil permeability index was calculated from clay and sand content as using $SPI = \text{sand (\%)} - \text{clay (\%)}$.

Table 3. Reclassification of flood hazard factors

Factor	Very high (5)	High (4)	Moderate (3)	Low (2)	Very low (1)
Elevation (m)	0–200	200–400	400–700	700–1,000	>1,000
Slope (°)	0–2	2–5	5–10	10–15	>15
Mean annual rainfall (mm)	>1,100	900–1,100	700–900	500–700	0–500
Distance to rivers (m)	0–500	500–1,000	1,000–2,000	2,000–3,000	>3,000
Soil permeability index (%)	–26 to 0	>0 to 20	>20 to 40	>40 to 60	>60 to 84
Land use/land cover	Built-up, wetlands, water bodies	Bare/sparse vegetation	Cropland	Grassland, shrubland	Tree cover

Table 5. Factor weights for the flood hazard index

Factor	Original weight (%)	Justification
Elevation	35	Low-lying land collects runoff and river overflow.
Slope	20	Controls the velocity and direction of runoff.
Rainfall	15	Main trigger of pluvial and fluvial floods.
Distance to rivers	15	Land near river channels floods first when rivers overflow.
Soil permeability	Not weighted	Low permeability increases surface runoff.
Land use/land cover	15	Built-up and bare surfaces increase runoff.
Total	100	

3.4. Exposure

Exposure (E) refers to the population and human settlements located in areas that are susceptible to flooding. In this study, exposure is used to assess the extent to which people are geographically situated in areas where floods may occur. It considers the spatial distribution of the population in relation to flood-prone areas, helping to identify communities that may be directly affected when flooding occurs. By incorporating exposure into the flood risk assessment, the study distinguishes areas with a potential flood hazard from those where people are actually present and may experience its impacts. This provides a basis for identifying populations that may require targeted flood preparedness, emergency response, and risk reduction measures.

3.6. Integrated Flood Risk

Integrated flood risk (Equation 1 and Figure 8) was assessed by combining three key dimensions: flood hazard, exposure, and vulnerability. Flood hazard (H) represents the likelihood and potential severity of flooding in a given area, while exposure (E) refers to the people, infrastructure, buildings, and other assets located in flood-prone areas. Vulnerability (V) describes the socioeconomic conditions that influence the ability of individuals and communities to anticipate, withstand, respond to, and recover from flood events.

The integrated flood risk was calculated by multiplying these three components, as expressed in the following equation:

$$R = H \times E \times V \text{ -----1}$$

where R represents integrated flood risk, H denotes flood hazard, E represents exposure, and V refers to socioeconomic vulnerability. This approach recognizes that flood risk is shaped not only by the

presence of a physical hazard but also by the concentration of exposed people and assets and their capacity to cope with its impacts. The resulting risk index was used to identify and map areas with varying levels of integrated flood risk.

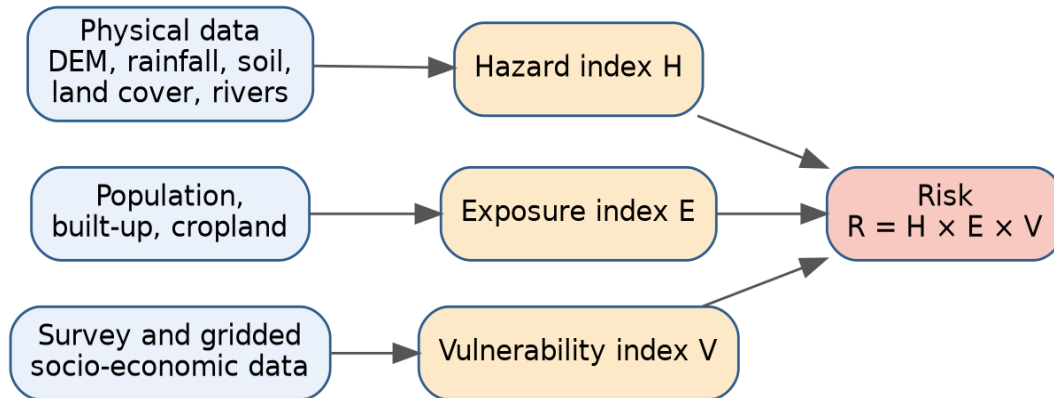


Figure 8. Methodological workflow of the study

IV. RESULTS

4.1. Hazard Mapping: Physical Vulnerability

The flood vulnerability assessment for Northwest Nigeria classified the region into five levels, ranging from very low to very high, based on the combined influence of key physical and environmental factors presented in Table 2. This classification provides a clear spatial representation of areas with varying likelihood of flooding across the region and serves as a foundation for identifying priority zones for flood risk management, planning, and intervention. Figure 8 depicts regional flood vulnerability across the entire Northwest region. The flood map reveals a clear spatial pattern across Northwest Nigeria: very high and high susceptible zones are concentrated along

major river corridors, low-lying floodplains, areas with gentle slopes and poor soil permeability. Moderate susceptible zones dominate transitional landscapes where terrain and drainage conditions vary. Low and very low susceptible zones occur mainly in elevated terrain, well-drained landscapes and areas with vegetation cover. The summary statistics of the flood susceptibility, as concisely presented in Table 3, indicate that over half of the region (50.66%) falls within areas of moderate flood susceptibility. Areas with low and very low flood susceptibility together account for 32.58% of the region, while high and very high susceptibility zones cover 16.76% and are mainly in Kebbi, Sokoto, Zamfara and parts of Jigawa and Kano.

Table 2. Summary statistics of the northwest region to flood

	Vulnerability	Area_sqkm	%
Northwest region	Very low	10646.15283	5.08
	Low	57669.16026	27.50
	Moderate	106221.615	50.66
	High	25370.83181	12.10
	Very high	9776.467105	4.66
Total		209684.227	100.00

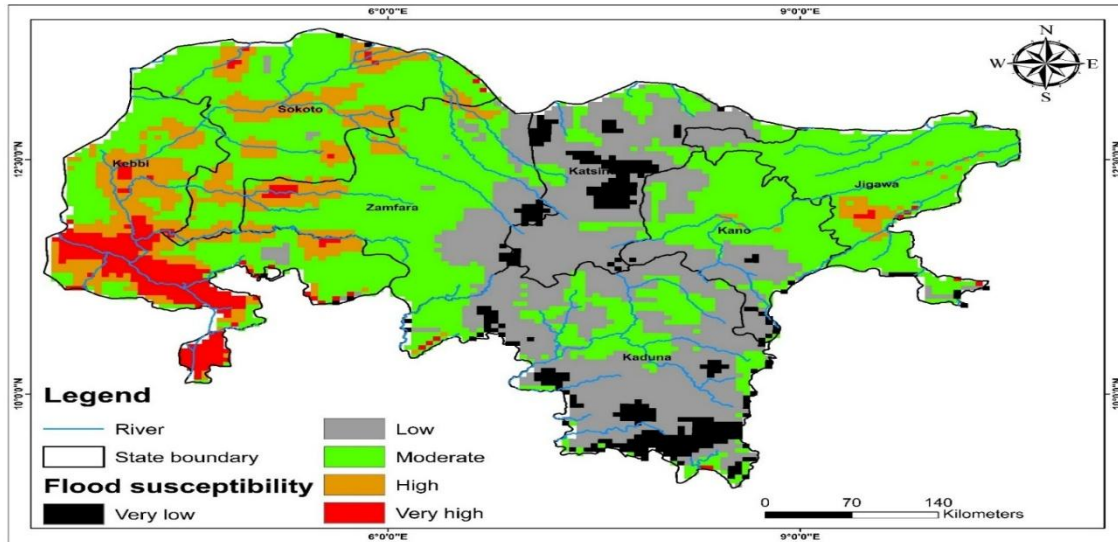


Figure 9. Comprehensive flood risk map of Northwest Nigeria

States-wise, the analysis reveals clear spatial variations in flood susceptibility across the region. As concisely summarised in Table 3, Jigawa State is overwhelmingly dominated by moderate flood susceptibility, accounting for 85.83% of its total area, with only small proportions falling within high and very high susceptibility classes. Kano State also exhibits a predominantly moderate susceptibility profile (63.23%), although a substantial share of the state (33.87%) lies within the low susceptibility category, indicating relatively better drainage conditions in many areas. In contrast, Kaduna and Katsina States are largely characterised by low to very low flood susceptibility, together accounting for over 70% of their respective land areas. This suggests comparatively lower flood likelihood across much of these states, with only marginal extents classified as high or very high susceptibility.

Sokoto State presents a different pattern, with a significant proportion of its area (29.94%) classified as high flood susceptibility, alongside a dominant moderate susceptibility zone (67.98%), highlighting elevated flood concern in several parts of the state. Similarly, Zamfara State is largely dominated by moderate susceptibility (67.89%), but also contains notable areas of high and very high susceptibility (approximately 11.66% combined). Kebbi State stands out as the most flood-exposed state in the region, with more than 54% of its land area classified as high to very high flood susceptibility, indicating extensive flood-prone zones that require urgent attention in flood risk management and planning.

Table 3. Summary statistics of the Northwest Nigeria states for flood

States	Vulnerability	Area km ²	Percentage (%)
Jigawa	Very low	179.9349774	0.80
	Low	1289.534005	5.75
	Moderate	19253.04258	85.83
	High	1469.468982	6.55
	Very high	239.9133032	1.07
	Total	22431.89385	100.00
Kano	Susceptibility	Area_sqkm	Percentage (%)

	Very low	419.8482806	2.03
	Low	6987.474956	33.87
	Moderate	13045.28586	63.23
	High	179.9349774	0.87
	Total	20632.54408	100.00
Kaduna	Susceptibility	Area_sqkm	Percentage (%)
	Very low	5727.930114	13.02
	Low	26060.58256	59.24
	Moderate	11995.66516	27.27
	High	59.9783258	0.14
	Very high	149.9458145	0.34
	Total	43994.10197	100.00
Katsina	Susceptibility	Area_sqkm	Percentage (%)
	Very low	3298.807919	13.92
	Low	16044.20215	67.72
	Moderate	4348.428621	18.35
	Total	23691.43869	100.00
Sokoto	Susceptibility	Area_sqkm	Percentage (%)
	Very low	59.9783258	0.19
	Low	239.9133032	0.75
	Moderate	21652.17561	67.98
	High	9536.553802	29.94
	Very high	359.8699548	1.13
	Total	31848.491	100.00
Zamfara	Susceptibility	Area_sqkm	Percentage (%)
	Very low	539.8049322	1.57
	Low	6507.648349	18.89
	Moderate	23391.54706	67.89
	High	3658.677874	10.62
	Very high	359.8699548	1.04
	Total	34457.54817	100.00
Kebbi	Susceptibility	Area_sqkm	Percentage (%)
	Very low	89.9674887	0.25
	Low	509.8157693	1.42
	Moderate	15894.25634	44.31
	High	10766.10948	30.02
	Very high	8606.889752	24.00

	Total	35867.03883	100.00
--	-------	-------------	--------

4.2. Flood Risk Distribution

The flood risk assessment refines susceptibility results by accounting for settlement exposure. Thus, flood risk here reflects where people and assets intersect with susceptible zones. This distinction is critical for policy prioritisation. However, only settlements in very high and high flood susceptible zones where floods are highly likely to occur are identified. These are depicted in Figure 9. Areas at very high risk of flooding across the region, covering about 1,889 km², are mainly located in Kebbi State, with a few portions

in parts of Jigawa, Sokoto and Zamfara, involving about 92 settlements. Furthermore, areas at high risk of floods across the region cover about 6,058 km² and are mainly located in Kebbi, Sokoto, Jigawa and Zamfara, with a few portions in Kano and Kaduna involving about 337 settlements. Figures 10 Figure 11 and Figure 12, respectively, depict the settlements at very high and high risk of Floods in the Northwest region.

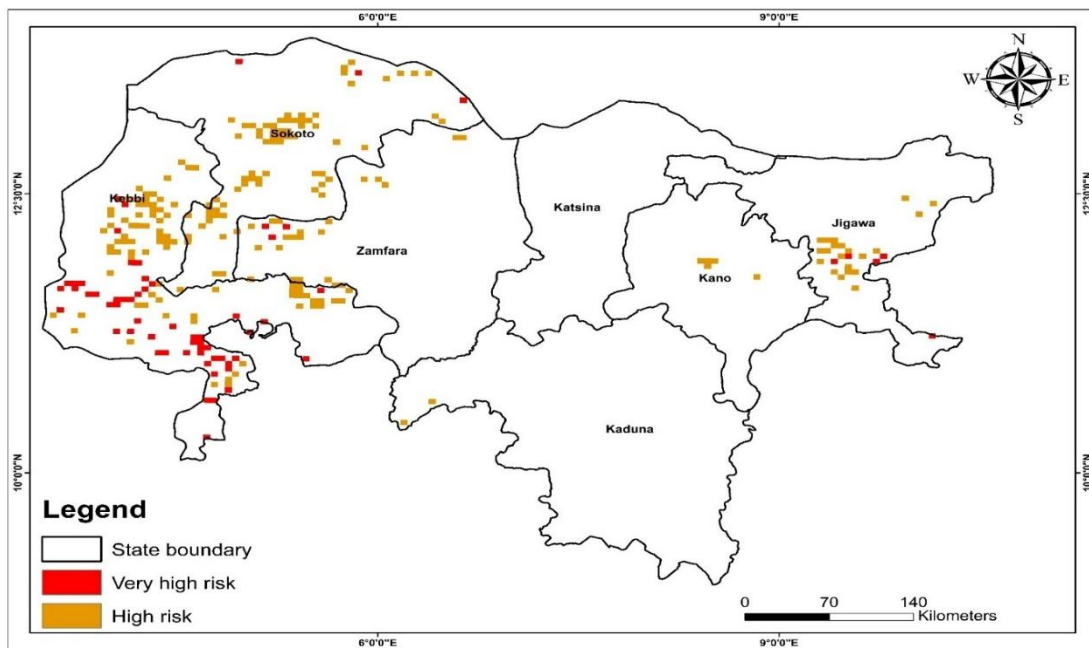


Figure 10. Locations at very high and high risk of flood in Northwest Nigeria

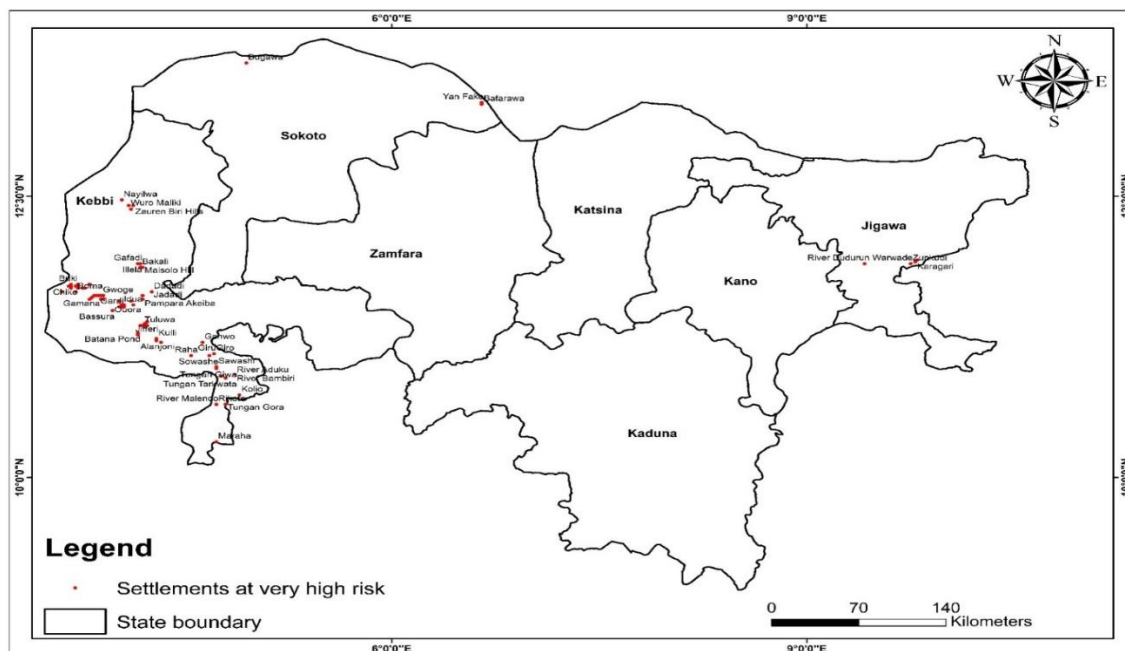


Figure 11. Location of settlements at very high risk of flood in Northwest Nigeria

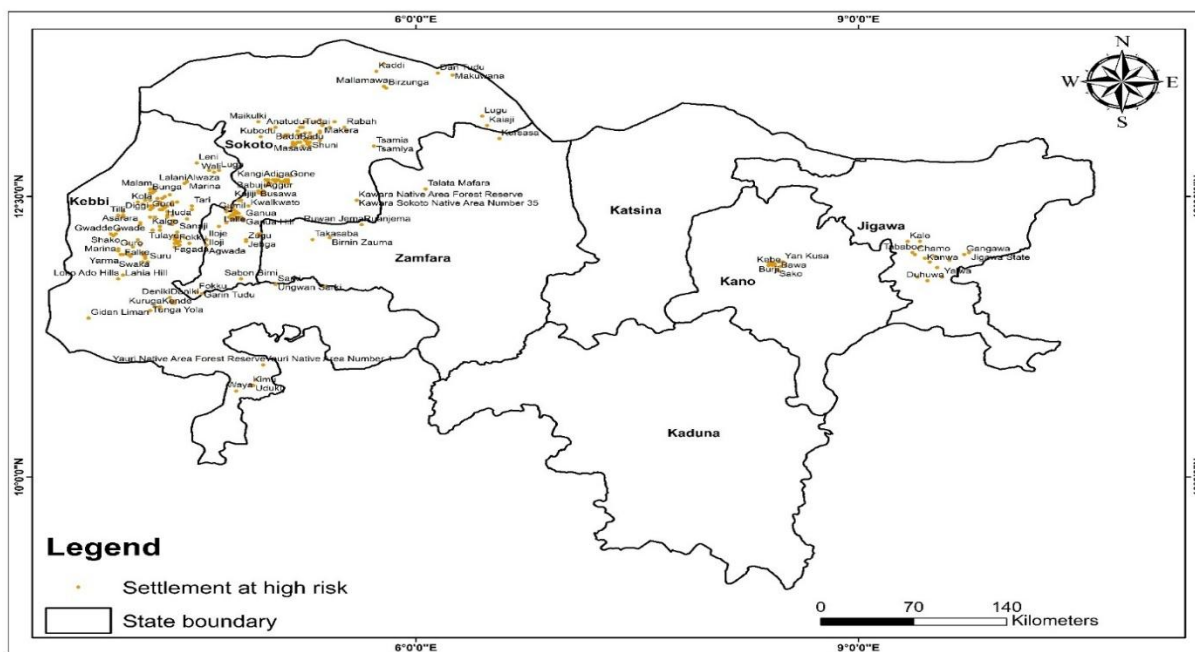


Figure 12. Location of settlements at high risk of flood in Northwest Nigeria

V. DISCUSSION

The high flood hazard levels identified in Kebbi and Sokoto may be associated with their proximity to major river systems, including the Niger, Sokoto-Rima and Rima, as well as the extensive floodplains and relatively low-lying terrain found in these areas. These

geographical characteristics can encourage water accumulation, river overflow and the widespread movement of floodwaters during periods of heavy rainfall. In contrast, although the Hadejia-Jama'are floodplain in Jigawa experiences frequent flooding, much of the area is classified as having moderate flood hazard in the present assessment. This difference may

reflect the spatial resolution of the input datasets, the criteria selected for the analysis, or the weights assigned to individual flood-conditioning factors within the model. For example, coarse-resolution data may not adequately capture local variations in elevation, drainage patterns and floodplain characteristics, while the weighting system may give greater importance to factors that do not fully represent the flooding processes in the Hadejia-Jama'are basin. However, these are possible explanations rather than confirmed causes. Further investigation, including sensitivity analysis of the factor weights and comparison with higher-resolution terrain data and historical flood records, is therefore necessary to determine why the floodplain is predominantly classified as having moderate hazard.

VI. CONCLUSION

This study produced an integrated flood risk assessment for North-western Nigeria that combines physical hazard, exposure and socio-economic vulnerability in a GIS-based MCDA framework. The results show that flood hazard is highest in Kebbi and Sokoto, mainly because of low-lying floodplains and proximity to rivers. When exposure and socio-economic vulnerability are included, 27.75 % of the region, comprising the states of Kebbi (9 LGAs), Zamfara (2 LGAs) and Sokoto (1 LGA), stands out as having very high flood risk, whereas areas of high flood risk are found mainly in Kebbi (15 LGAs), Sokoto (19 LGAs), Kano (4 LGAs) and Jigawa (3 LGAs)

REFERENCES

- [1] Adefolalu, D. O. (1986). Rainfall trends in Nigeria. *Theoretical and Applied Climatology*, 37(4), 205–219. [Springer](#)
- [2] Abdussalam, A. F., Monaghan, A. J., Steinhoff, D. F., Dukic, V. M., Hayden, M. H., Hopson, T. M., Thornes, J. E., & Leckebusch, G. C. (2014). The impact of climate change on meningitis in northwest Nigeria: An assessment using CMIP5 climate model simulations. *Weather, Climate, and Society*, 6(3), 371–379.
- [3] Abu-hanifa, B., Abdussalam, A. F., Baba, S. U., Isa, Z., & Ugya, A. Y. (2025). A comprehensive review of flood monitoring and evaluation in Nigeria. *International Journal of Energy and Water Resources*, 9(4), 1741–1765. [Springer](#)
- [4] Bello, A. A., Abua, M. A., Yelwa, S. A., Undiyaundeye, F. A., Iwara, A. I., Abutunghe, M. A., Bassey, B. J., Egbonyi, D. E., & Owalom, S. O. (2022). Geospatial Mapping of Areas at Risk to flood Along Sokoto. *Environment and Ecology Research*, 10(6), 806–823.
- [5] Field, C. B. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability - Summary for Policymakers*. <bound method Organization.get_name_with_acronym of <Organization: Intergovernmental Panel on Climate Change>>.
- [6] Idris, M., Mustapha, A., & Komolafe, A. A. (2025). Application of GIS and MCDA in flood susceptibility modeling in Jigawa State. Nigeria. *Water and Soil Management and Modeling*, 5(4), 1–14. [Water and Soil Management and Modeling](#)
- [7] Ibrahim, U. A., Alkali, A. N., Sanyaolu, B. O., & Usman, B. (2022). Nigerian Water Resources Management – An Overview. *Arid Zone Journal of Engineering, Technology & Environment*, 18(1), 23–30. [AZOJETE](#)
- [8] Komolafe, A. A., Abdul-Azeez Adegboyega, S., Akinluyi, F. O., & Komolafe, A. A. (2015). A Review of Flood Risk Analysis in Nigeria.
- [9] Muhammad, T. M., Mohammad, H. A., Abdullahi, B., Muktar, A., Usman, A. K., Igusi, E. O., & Auwal, A. (2026). Assessment of Flood Risk and Adaptation Strategies in Hadejia River Basin, Nigeria. *FUDMA Journal of Sciences*, 10(2), 301–325. [FUDMA Journal of Sciences](#)
- [10] Nnah, S. I., & Ikwueze, U. H. (2025). GIS Based Multi-Hazard Risk Assessment In Nigeria: Flooding, Erosion, And Desertification In Sudano-Sahelian Region, Northwest Nigeria. [Zenodo](#)
- [11] Office of the Surveyor-General of the Federation. (n.d.). Retrieved September 29, 2026, from [Office of the Surveyor-General of the Federation](#)
- [12] Tudunwada, I. Y., & Ahmad, A. (2026). Geospatial Profiling of Flood Victims and Associated Losses of Lives and Properties in the Aftermath Of 2022 Floods in Jigawa State,

Northern Nigeria. *FUDMA Journal of Sciences*,
10(7), 16–26. [FUDMA Journal of Sciences](#)