



Science Forum (Journal of Pure and Applied Sciences)

Journal Homepage: <https://atbuscienceforum.com.ng/index.php/jpas>



GIS-Based Flood Risk Mapping and Mitigation Planning in Ningi Local Government Area, Bauchi State, Nigeria

Mahmood Sulaiman, Jibrin Mohammad, Lumi Haruna, I.Y Chindo

Environmental Standard Node, Sustainable Procurement, Environmental and Social Standard Project, Centre of Excellence, (SPESSCE)
Abubakar Tafawa Balewa University, Bauchi, Nigeria.

Abstract

Flooding remains a major environmental hazard in Nigeria. This study assessed flood patterns and spatial susceptibility in Ningi Local Government Area (LGA), Bauchi State, using Geographic Information System (GIS) techniques. Digital Elevation Models (DEMs), drainage analysis, and spatial mapping were applied to examine terrain and drainage characteristics, delineate flood-prone locations, and assess deficiencies in existing drainage infrastructure. Flooding reflects interacting physical and human factors. Topography-induced surface runoff contributes to the concentration and movement of stormwater, while inadequate drainage infrastructure constrains its conveyance. Settlement along waterways increases exposure to flooding, and poor waste disposal practices may obstruct drainage pathways and worsen local inundation. Together, these conditions point to the need for spatially informed interventions that address both runoff management and patterns of human settlement. To mitigate flood impacts, the study proposes a phased strategy comprising canal construction, earth dam development, and land-use regulation. Phasing is intended to support the orderly implementation of structural measures alongside controls on development in vulnerable areas. GIS provides a practical decision-support framework for identifying flood-prone areas, relating susceptibility to terrain and drainage conditions, and informing the prioritization of mitigation actions. The study concludes that applying GIS to flood assessment in Ningi can support more sustainable flood management by linking spatial evidence with infrastructure planning and land-use decisions. The findings offer a basis for local authorities to target interventions, improve drainage planning, and guide settlement regulation in areas exposed to flooding, while recognizing that effective risk reduction requires coordinated attention to topography, infrastructure, waterways, and waste management.

Keywords

Flooding, GIS, Ningi LGA, DEM, Flood Hazard Mapping, Mitigation.



1. Introduction

Flooding is one of the most devastating natural hazards affecting human populations globally, with increasing frequency and intensity due to climate variability and anthropogenic activities. In recent years, the impact of flooding has become more pronounced in developing countries such as Nigeria, where rapid urbanization, poor infrastructure, and environmental mismanagement exacerbate vulnerability. Flood disasters result in significant loss of lives, destruction of infrastructure, displacement of communities, and disruption of socio-economic activities (Muhammad, 2024).

Globally, floods are responsible for a substantial proportion of natural disaster-related damages. Advances in geospatial technologies have revealed that flood events are becoming more complex, requiring integrated approaches for effective monitoring, assessment, and mitigation. Geographic Information System (GIS) has emerged as a critical tool in addressing these challenges, enabling spatial analysis, visualization, and modeling of flood risks using multi-source data (Nguyen et al., 2021).

In Nigeria, flooding has become an annual occurrence, particularly during the rainy season, affecting several states including Bauchi State. The 2022 flood disaster was one of the most severe in recent history, resulting in over 600 deaths, displacement of more than 1.4 million people, and destruction of thousands of homes and farmlands (Federal Government of Nigeria, 2022). Similarly, the 2024 flood events affected over 30 states, including Bauchi State, causing widespread damage, displacement, and economic loss (Wikipedia, 2024). These recurring events highlight the urgent need for effective flood risk assessment and mitigation strategies.

Bauchi State, located in the northeastern region of Nigeria, is particularly vulnerable to flooding due to its climatic conditions, topography, and drainage patterns. Recent assessments indicate that thousands of individuals have been affected by flooding across various local government areas in the state, with significant impacts on livelihoods and infrastructure (International Organization for Migration [IOM], 2024). Ningi Local Government Area, being part of this

region, experiences seasonal flooding that affects agricultural productivity, settlements, and transportation networks.

Flooding in Ningi LGA is influenced by both natural and human factors. Natural factors include intense rainfall, low-lying terrain, and proximity to water bodies, while human-induced factors include poor urban planning, deforestation, blockage of drainage channels, and uncontrolled settlement in flood-prone areas. The interaction of these factors increases the susceptibility of the area to flood hazards, making it necessary to adopt modern techniques for effective assessment and mitigation.

Geographic Information System (GIS) plays a crucial role in flood risk assessment by integrating spatial and non-spatial data to produce detailed maps and models. GIS enables the analysis of terrain characteristics such as elevation, slope, drainage density, and land use/land cover, which are essential for identifying flood-prone areas. Studies have shown that GIS-based approaches provide accurate and reliable results for flood mapping and risk assessment, making them indispensable tools for disaster management (Aja et al., 2024).

Recent studies conducted in Bauchi State have demonstrated the effectiveness of GIS in analyzing flood vulnerability and land use patterns. For instance, Alhaji (2025) used GIS and remote sensing techniques to classify flood vulnerability zones in Bauchi metropolis, identifying areas with high, moderate, and low susceptibility to flooding. The study highlighted the importance of integrating land use planning with flood risk management to reduce vulnerability and enhance resilience.

Furthermore, modern GIS techniques incorporate advanced analytical methods such as multi-criteria decision analysis (MCDA), fuzzy logic, and spatial interpolation to improve the accuracy of flood risk assessment. A recent study in Bauchi metropolis applied fuzzy-AHP and spatial interpolation techniques to map flood impact hotspots, demonstrating the capability of GIS in identifying areas most affected by flood events (Kafi et al., 2026).

Despite the availability of these advanced tools, there is still a significant gap in the application of GIS for

flood assessment and mitigation in many local government areas, including Ningi. Traditional methods of flood management often rely on reactive approaches rather than proactive planning, leading to repeated losses and increased vulnerability. Therefore, there is a need to adopt GIS-based approaches to provide accurate, data-driven insights for effective flood management in the area.

This study seeks to assess flooding in Ningi Local Government Area using Geographic Information System (GIS) techniques and propose appropriate mitigation measures. By integrating spatial data such as elevation, land use, and drainage patterns, the study aims to identify flood-prone areas and provide recommendations for reducing flood risks. The findings of this study will contribute to improved disaster management, urban planning, and sustainable development in Ningi LGA and similar environments.

2. Problem Statement and Justification

Ningi LGA experiences recurrent flooding and erosion that damage infrastructure and disrupt socio-economic activities. Previous interventions have often

been localized and inadequate because they failed to consider catchment-wide hydrological processes. This study provides a GIS-based approach for understanding flood dynamics and proposing sustainable mitigation measures.

3. Aim and Objectives

The aim of the study was to analyze topographical and drainage patterns responsible for flooding in Ningi and propose GIS-derived mitigation strategies. Objectives included mapping terrain characteristics, identifying flood hazard zones, assessing drainage deficiencies, and proposing strategic mitigation infrastructure.

4. Methodology

GIS techniques were employed using Digital Elevation Models (DEM), drainage analysis, and spatial mapping to identify flood-prone areas. Terrain characteristics such as elevation and slope were analyzed to delineate runoff pathways and flood accumulation zones.

5. Results and Discussion

Table 4.1: Socio-Demographic Characteristics of Respondents (N = 250)

Variable	Category	Frequency	Percentage (%)
Sex	Male	140	56.0
	Female	110	44.0
Age	Below 20	30	12.0
	21-30	80	32.0
	31-40	70	28.0
	41-50	50	20.0
	51 and above	20	8.0
Marital Status	Single	60	24.0
	Married	150	60.0
	Divorced	15	6.0
	Widowed	25	10.0

Level of Education	No formal education	40	16.0
	Primary	70	28.0
	Secondary	90	36.0
	Tertiary	50	20.0
Occupation	Farming	110	44.0
	Trading	60	24.0
	Civil servant	40	16.0
	Artisan	25	10.0
	Other	15	6.0
Length of Residence	Less than 5 years	50	20.0
	5-10 years	90	36.0
	Above 10 years	110	44.0
Total		250	100.0

Source: Questionnaire, 2026

From table 4.1 above the socio-demographic distribution of respondents shows a slightly higher proportion of males, who constitute 140 (56.0%), while females account for 110 (44.0%). This indicates that both genders are fairly represented in the study, although males are slightly more dominant, which may reflect their higher involvement in outdoor and flood-prone activities such as farming and trading.

In terms of age distribution, the majority of respondents fall within the economically active age groups. The highest proportion is within the 21-30 years category with 80 (32.0%), followed by 31-40 years with 70 (28.0%), and 41-50 years with 50 (20.0%). Respondents below 20 years constitute 30 (12.0%), while those aged 51 years and above are the least represented with 20 (8.0%). This implies that most respondents are adults who are likely to have experienced or observed flooding impacts directly.

Regarding marital status, married respondents dominate the study with 150 (60.0%), followed by single respondents with 60 (24.0%), widowed with 25

(10.0%), and divorced with 15 (6.0%). This suggests that the study largely reflects the views of family-oriented individuals who may be more concerned about the effects of flooding on households and livelihoods. The educational background of respondents shows that secondary education holders constitute the highest proportion at 90 (36.0%), followed by those with primary education at 70 (28.0%), tertiary education at 50 (20.0%), and respondents with no formal education at 40 (16.0%). This indicates that most respondents possess at least basic literacy, which may enhance their understanding of flood-related issues and GIS-based interventions.

In terms of occupation, farming is the dominant livelihood activity with 110 (44.0%), followed by trading with 60 (24.0%), civil service with 40 (16.0%), artisans with 25 (10.0%), and others with 15 (6.0%). This reflects the agrarian nature of Ningi LGA and highlights the vulnerability of the population, as farming communities are highly exposed to flood hazards.

Finally, the length of residence shows that a significant proportion of respondents have lived in the area for a long period, with 110 (44.0%) staying above 10 years, 90 (36.0%) between 5-10 years, and 50

(20.0%) less than 5 years. This indicates that most respondents have adequate local experience and are likely knowledgeable about historical flood patterns in the area.

Table 4.2: Mean and Standard Deviation of Flood-Prone Area Identification (n = 250)

S/N	Questionnaire Item	Mean ($\bar{x}$)	Std. Deviation (SD)	Remark
7	Awareness of flood-prone areas in the community	1.78	0.42	High awareness
8	Flood occurrence every rainy season	2.31	0.58	High seasonal occurrence
9	Areas most affected by flooding (spatial location)	3.62	1.12	Dominantly low-lying areas/farmlands
10	Personal experience of flooding	1.85	0.36	Majority have experienced flooding
11	Frequency of flooding occurrence	2.41	0.69	Moderate to high frequency

Source: Questionnaire, 2026

From table 4.2 above the results presented in the mean and standard deviation table provide insights into residents' perceptions and experiences of flooding in Ningi Local Government Area. The mean score of 1.78 indicates that most respondents are aware of flood-prone locations within their communities. The relatively low standard deviation (0.42) shows that responses were closely clustered, meaning there is general agreement among residents about the existence of flood-prone areas. The mean value of 2.31 suggests that flooding is a common phenomenon in the study area, occurring frequently during rainfall periods. The standard deviation of 0.58 shows moderate variation in responses, indicating that while flooding is widespread, its intensity or frequency may differ slightly across communities.

For the spatial location of flood-prone areas the higher mean value of 3.62 reflects that respondents strongly identified specific physical locations as being

more affected by flooding. These include low-lying areas, farmlands, roads, and river/stream banks. The relatively high standard deviation (1.12) indicates variation in responses, which suggests that different communities experience flooding in different spatial patterns, with no single uniform flood location across the LGA.

In terms of personal experience of flooding the mean score of 1.85 shows that a significant proportion of respondents have personally experienced flooding. The low standard deviation (0.36) indicates strong consensus, meaning most households have been affected directly or indirectly by flood events. Finally, for frequency of flooding occurrence the mean value of 2.41 suggests that flooding occurs between occasional and annual intervals, confirming that flooding is a recurring environmental issue in Ningi LGA. The standard deviation of 0.69 reflects moderate variability, implying that some communities experience flooding more frequently than others.

Flood Prone Areas in Ningi Local Government Area



Figure 1: Shows High Velocity Runoff in the Study Area



Figure 2: Shows Pattern of Erosion in the Study Area



Figure 3: Shows the Level of Degradation in the Study Area



Figure 4: Shows Impact of Erosion due to Human Induce Factor

Table 4.3: Mean and Standard Deviation of Spatial Pattern and Characteristics of Flooding (n = 250)

S/N	Questionnaire Item	Mean (X)	Standard Deviation (SD)	Remark
12	Flooding in your area is usually seasonal and follows a predictable pattern	3.42	0.78	Agreed
13	Heavy rainfall and poor drainage are the major factors contributing to flooding	3.61	0.69	Strongly Agreed
14	Flood water in the area flows mainly towards farmlands and residential areas	3.35	0.81	Agreed
15	Drainage systems are available in most parts of the community	2.48	0.92	Disagreed
16	Existing drainage systems are poorly effective in controlling flooding	3.56	0.73	Strongly Agreed

Source: Questionnaire, 2026

From table 4.3 above the results show respondents' perceptions on the spatial pattern and characteristics of flooding in Ningi Local Government Area (LGA), based on 250 valid responses.

The mean score of 3.42 indicates that most respondents agreed that flooding in their area is largely seasonal and follows a predictable pattern, especially during the rainy season. This suggests that flooding is not random but is strongly associated with rainfall periods. The relatively low standard deviation of 0.78 shows that there is general agreement among respondents across different communities.

The high mean score of 3.61 indicates a strong agreement that heavy rainfall and poor drainage systems are the major contributors to flooding in the study area. This confirms that flooding in Ningi LGA is largely environmentally and infrastructurally driven rather than purely natural. The low standard deviation of 0.69 also shows a high level of consistency in responses, meaning most respondents share similar views.

The mean score of 3.35 shows that respondents agreed that floodwater generally flows towards farmlands and residential areas, indicating that human settlements are highly exposed to flood hazards. This finding highlights the vulnerability of both agricultural land and housing structures. The slightly higher standard deviation of 0.81 suggests that experiences vary across different locations within the LGA.

The low mean score of 2.48 indicates that most respondents disagreed that drainage systems are adequately available in their communities. This implies that drainage infrastructure is either insufficient or completely absent in many areas. The relatively high standard deviation of 0.92 reflects differences in infrastructure availability between communities, with some areas slightly better served than others. The high mean score of 3.56 shows that respondents strongly agreed that existing drainage systems are poorly effective in controlling flooding. This suggests that even where drainage systems exist, they are inadequate, blocked, poorly constructed, or poorly maintained. The low standard deviation of 0.73 indicates that this is a widely shared perception across the study area.

The mean score of 3.42 indicates that most respondents agreed that flooding in their area is largely seasonal and follows a predictable pattern, especially during the rainy season. This suggests that flooding is not random but is strongly associated with rainfall periods. The relatively low standard deviation of 0.78 shows that there is general agreement among respondents across different communities.

The high mean score of 3.61 indicates a strong agreement that heavy rainfall and poor drainage systems are the major contributors to flooding in the study area. This confirms that flooding in Ningi LGA is largely environmentally and infrastructurally driven rather than purely natural. The low standard deviation of 0.69 also shows a high level of consistency in responses, meaning most respondents share similar views.

The mean score of 3.35 shows that respondents agreed that floodwater generally flows towards farmlands and residential areas, indicating that human settlements are highly exposed to flood hazards. This finding highlights the vulnerability of both agricultural land and housing structures. The slightly higher standard deviation of 0.81 suggests that experiences vary across different locations within the LGA.

The low mean score of 2.48 indicates that most respondents disagreed that drainage systems are adequately available in their communities. This implies that drainage infrastructure is either insufficient or completely absent in many areas. The relatively high standard deviation of 0.92 reflects differences in infrastructure availability between communities, with some areas slightly better served than others. The high mean score of 3.56 shows that respondents strongly agreed that existing drainage systems are poorly effective in controlling flooding. This suggests that even where drainage systems exist, they are inadequate, blocked, poorly constructed, or poorly maintained. The low standard deviation of 0.73 indicates that this is a widely shared perception across the study area.

Existing Pattern and Spatial Characteristic of Flooding Using Gis

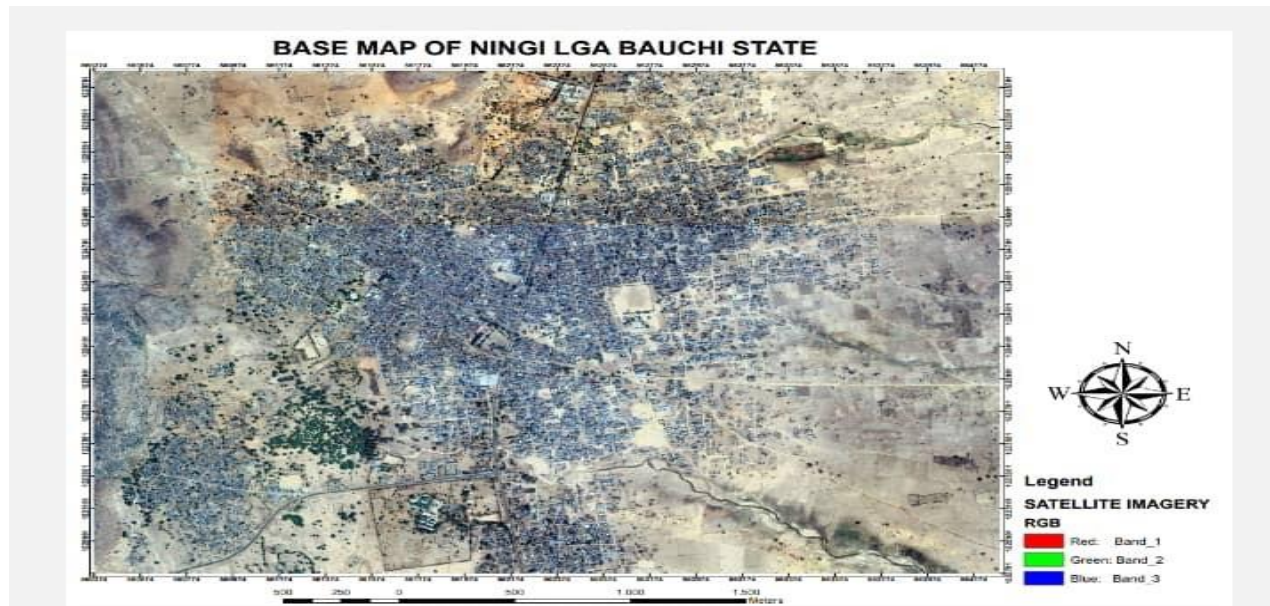


Figure 5: The Base Map Shows the Extent of the Study Area

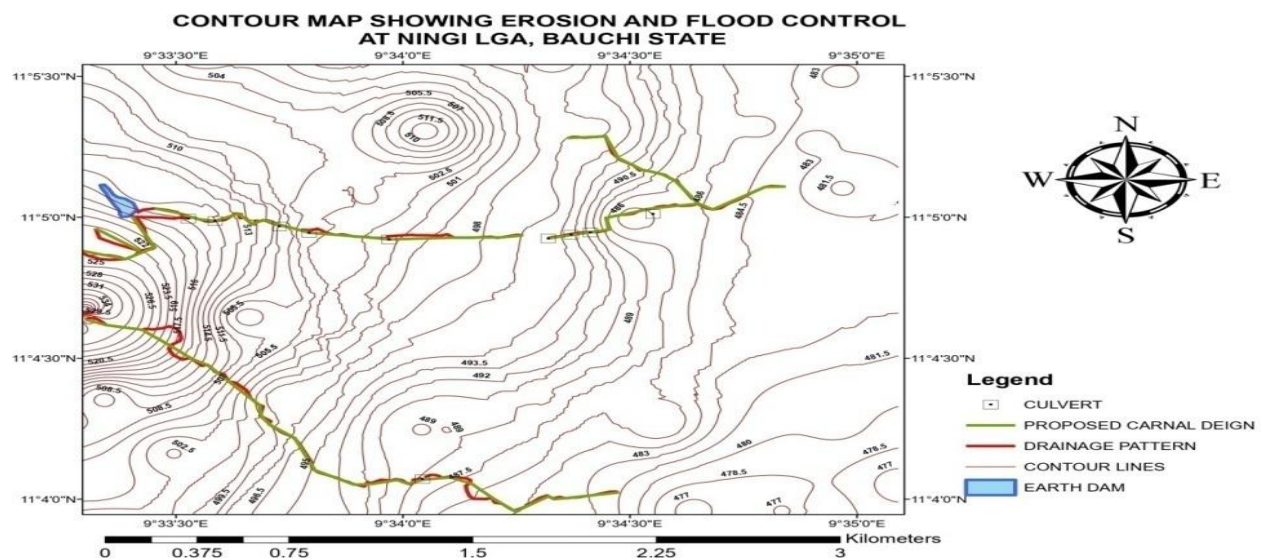


Figure 6: Contour Map Showing Erosion and Flood Control of Proposed Canal Design Pattern

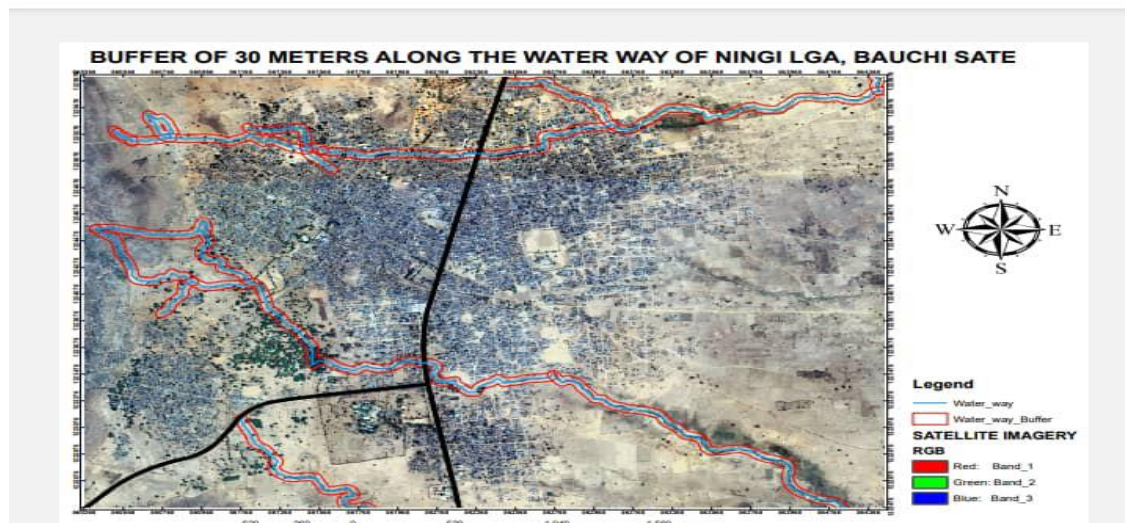


Figure 7: Shows the 30 Meters Radius Along the Water Ways in the Study Area

Table 4.4: Mean and Standard Deviation of Flood Impact Variables

S/ N	Item	Mean ($\bar{X}$)	Std. Deviation (SD)	Interpretation
17a	Destruction of houses	0.82	0.39	High occurrence
17b	Crop loss	0.88	0.32	Very high occurrence
17c	Road damage	0.76	0.43	High occurrence
17d	Water contamination	0.84	0.37	High occurrence
17e	Displacement of people	0.69	0.46	Moderate-High occurrence
18	Flooding affects income/livelihood	0.81	0.39	High impact
19a	Malaria	0.85	0.36	High occurrence
19b	Cholera	0.74	0.44	Moderate-High occurrence
19c	Skin diseases	0.71	0.45	Moderate occurrence
19d	Diarrhea	0.78	0.42	High occurrence
20	Severity of flooding impact	4.12	0.89	Severe impact
21	Relocation due to flooding	0.63	0.48	Moderate occurrence

Source: Questionnaire, 2026

The results of the mean and standard deviation analysis indicate that flooding has a significant and multidimensional effect on residents of Ningi Local Government Area. The findings show that destruction of houses ($\bar{X} = 0.82$), crop loss ($\bar{X} = 0.88$), road damage ($\bar{X} = 0.76$), water contamination ($\bar{X} = 0.84$), and displacement of people ($\bar{X} = 0.69$) are commonly experienced impacts of flooding in the study area.

Among these, crop loss recorded the highest mean value, suggesting that agriculture is the most affected sector, which is expected since many residents depend on farming for their livelihood.

The result further reveals that flooding has a high negative effect on income and livelihood ($\bar{X} = 0.81$). This implies that most respondents experienced economic hardship as a result of flood events, either

through loss of farmland, destruction of goods, or disruption of trading activities.

In terms of health impacts, diseases such as malaria ($X = 0.85$), diarrhea ($X = 0.78$), cholera ($X = 0.74$), and skin diseases ($X = 0.71$) were reported. Malaria recorded the highest mean value, indicating that stagnant floodwater creates favorable breeding conditions for mosquitoes, thereby increasing disease prevalence in the area.

The overall severity of flooding impact ($X = 4.12$, $SD = 0.89$) falls within the "severe" category, showing that

respondents perceive flooding as a major environmental and socio-economic problem in the study area. The relatively low standard deviation suggests that there is general agreement among respondents regarding the seriousness of flood impacts.

Finally, the result shows that relocation of people due to flooding ($X = 0.63$) is also occurring, though at a moderate level compared to other impacts. This indicates that while not all residents are displaced, a considerable proportion have experienced forced movement due to flood hazards.

Table 4.5: Mean and Standard Deviation of Flood Risk Mapping Awareness (n = 250)

S/ N	Statement	Mean ($\bar{x}$)	Standard Deviation (SD)	Decision
22	Are you aware that flood risk maps can be used to manage flooding?	0.78	0.42	High Awareness
23	Do you think GIS can help identify flood-prone areas in your community?	1.62	0.55	High Agreement
24	Would you support government efforts to map flood-risk areas in your community?	0.88	0.32	Strong Support
25	Do you think your community is properly represented in flood risk planning?	0.41	0.49	Low Representation

Source: Questionnaire, 2026

From the table 4.5 above the results presented in the table show the level of awareness, perception, and participation of respondents regarding flood risk mapping and GIS application in flood management within Ningi Local Government Area. The mean score of 0.78 indicates that a relatively high proportion of respondents are aware of the usefulness of flood risk maps. The low standard deviation of 0.42 suggests that responses were fairly consistent among participants, meaning most respondents shared similar views.

The mean values of 1.62 shows that respondents generally agree that Geographic Information System (GIS) can effectively identify flood-prone areas in their community. This relatively high mean indicates strong acceptance of GIS as a useful tool for flood analysis. The standard deviation of 0.55 reflects

moderate variation in responses, suggesting that while most respondents agree, a few had different opinions or were uncertain. The mean score of 0.88 reveals a strong level of support for government efforts in mapping flood-risk areas. The low standard deviation of 0.32 indicates a high level of consensus among respondents, showing that most residents are in agreement with the need for government intervention in flood risk mapping and planning.

However, the mean score of 0.41, which is relatively low. This suggests that many respondents believe their community is not properly represented in flood risk planning. The standard deviation of 0.49 indicates moderate variability in responses, meaning opinions are somewhat divided but lean towards dissatisfaction with current planning inclusion.

Table 4.6: Mean and Standard Deviation of Respondents on Flood Mitigation and Sustainable Planning (n = 250)

S/ N	Items	Mean ($\bar{x}$)	Std. Deviation (SD)	Decision
26	Drainage construction exists in the area	3.42	1.11	Agreed
	Dams/embankments exist in the area	2.18	1.03	Disagreed
	No formal flood control measure exists	3.67	0.98	Agreed
	Government intervention exists in the area	3.25	1.07	Agreed
27	Proper drainage system is the preferred mitigation method	4.56	0.62	Strongly Agreed
	Afforestation is preferred	4.21	0.81	Agreed
	Relocation from flood-prone areas is preferred	3.89	1.02	Agreed
	Flood warning systems are preferred	4.33	0.74	Strongly Agreed
	Waste management improvement is preferred	4.40	0.69	Strongly Agreed
28	Government should be responsible for flood control	4.62	0.58	Strongly Agreed
	Community leaders should be responsible	3.91	0.97	Agreed
	Individuals should be responsible	3.76	1.05	Agreed
	NGOs should be responsible	3.88	0.94	Agreed
29	Relocating people from flood-prone areas is necessary	4.28	0.83	Agreed
	Relocation is not necessary	2.14	1.12	Disagreed

Source: Questionnaire, 2026

From table 4.6 the results presented in the table show respondents' perceptions on flood control measures, preferred mitigation strategies, responsibility for flood control, and relocation decisions in Ningi Local Government Area. The findings indicate that respondents generally agree that drainage construction (Mean = 3.42) and government intervention (Mean = 3.25) exist in some parts of the study area. However, the relatively high mean score for "no formal flood control measure exists" (Mean = 3.67) suggests that many communities still lack adequate and organized flood control infrastructure. On the other hand, the low mean score for dams/embankments (Mean = 2.18) shows that such structural flood control measures are either absent or

not commonly experienced in the area. This implies weak structural flood protection in Ningi LGA.

The results reveal strong agreement among respondents that several mitigation strategies are important. The highest mean values were recorded for proper drainage system (Mean = 4.56), waste management improvement (Mean = 4.40), flood warning systems (Mean = 4.33), afforestation (Mean = 4.21) and relocation from flood-prone areas (Mean = 3.89) indicates that respondents strongly support both structural measures (drainage systems) and non-structural measures (early warning systems, afforestation, and waste management). It also shows awareness that flooding can be reduced through environmental management and planning.

Respondents strongly agreed that government should take the lead responsibility for flood control (Mean = 4.62). This is followed by agreement that community leaders (Mean = 3.91), NGOs (Mean = 3.88) and individuals (Mean = 3.76) should also play supportive roles. This result suggests that while respondents recognize shared responsibility, they still place the highest expectation on government intervention, reflecting reliance on public institutions for disaster management. The results show that respondents agree that relocating people from flood-prone areas is necessary (Mean = 4.28), while disagreement is recorded for the opposite view (Mean = 2.14). This indicates that many residents acknowledge relocation as a viable long-term solution, especially for highly vulnerable communities, although such decisions may depend on government support and availability of alternative settlement areas.

4.2 Discussion of Findings

The socio-demographic profile shows that most respondents are within active working age groups and are largely engaged in farming, trading, and informal economic activities. This implies high dependence on environmental resources such as land and water, making them more vulnerable to flood impacts. This finding is consistent with Aderogba (2022), who reported that rural communities in Nigeria are highly vulnerable to flooding due to their dependence on agriculture and low-income livelihoods. Similarly, Olanrewaju et al. (2019) observed that low-income populations in flood-prone areas often lack adaptive capacity, increasing their exposure to flood hazards. The study revealed that respondents are aware of flood-prone areas, particularly low-lying areas, riverbanks, and farmlands. Flooding was reported to occur frequently during rainy seasons.

This agrees with Adelekan (2023), who found that flood-prone areas in Nigerian settlements are usually located near drainage channels and floodplains due to poor land-use planning. Likewise, Jeb and Aggarwal (2022) noted that flood occurrence is strongly linked to topography and proximity to river systems. The findings also support GIS-based studies such as Ismail et al. (2020), which emphasized that spatial

identification of flood-prone areas is best achieved through integration of elevation and drainage datasets.

The study shows that flooding in Ningi LGA is mostly seasonal, influenced by heavy rainfall, poor drainage systems, and flat terrain. Floodwater often spreads into residential areas and farmlands. This aligns with Nkwunonwo et al. (2025), who stated that urban and rural flooding in Nigeria is largely driven by intense rainfall and inadequate drainage infrastructure. Similarly, Bai et al. (2023) highlighted that land use change and poor urban planning significantly alter natural drainage patterns, increasing flood risk. The observed spatial pattern also supports GIS-based findings by Sanyal and Lu (2022), who noted that flood dispersion is highly dependent on terrain slope and land cover characteristics.

The findings revealed that flooding causes destruction of houses, loss of farmlands, displacement of people, water contamination, and health issues such as malaria and cholera. This is consistent with Ajaero et al. (2024), who reported that flooding in Nigeria leads to severe socio-economic and health consequences, including displacement and disease outbreaks. Similarly, UNDRR (2022) emphasized that floods disproportionately affect agriculture-based communities, leading to food insecurity and poverty. The health-related impacts correspond with WHO (2021) findings, which linked flooding to increased risks of waterborne and vector-borne diseases due to contaminated water sources and stagnant water.

The study shows that respondents generally have limited awareness of GIS-based flood risk mapping, but strongly believe that GIS can improve flood management. This supports the work of Aderogba and Lawal (2023), who found that although GIS is highly effective in flood prediction and mapping, community awareness of its application remains low in many Nigerian rural areas. Similarly, Chen et al. (2024) emphasized that GIS and remote sensing significantly enhance flood risk zoning and disaster preparedness. The willingness of respondents to support flood risk mapping aligns with UN-Habitat (2023) recommendations that community participation is

essential in spatial planning and disaster risk reduction.

Findings indicate that respondents strongly support improved drainage systems, flood warning systems, waste management, afforestation, and relocation from high-risk areas. They also believe government should take primary responsibility for flood control. This agrees with NEMA (2020), which emphasized that effective flood management in Nigeria requires a combination of structural and non-structural measures, including drainage improvement and early warning systems. Similarly, Olajuyigbe et al. (2022) found that poor waste disposal and blocked drainage systems are major contributors to urban flooding in Nigeria. The support for afforestation aligns with FAO (2023), which highlights the role of vegetation in reducing surface runoff and improving soil infiltration. The strong reliance on government intervention reflects findings by Adelekan and Asiyanbi (2025), who observed that communities in flood-prone areas often depend heavily on government assistance rather than community-based resilience strategies.

The study demonstrates that flooding in Ningi LGA is influenced by environmental, physical, and human factors, including topography, rainfall intensity, poor drainage systems, and land-use practices. These

findings strongly support previous GIS-based flood studies that emphasize the importance of spatial analysis in identifying flood-prone zones. The integration of community perception data with GIS analysis confirms that flood risk in the area is both physically observable and socially experienced. This supports the assertion by Smith and Ward (2021) that flood risk is a combination of hazard exposure and human vulnerability. Furthermore, the study highlights the importance of combining GIS-based spatial modeling with community-based data collection for effective flood risk management.

The findings are consistent with existing literature on flood risk in Nigeria and globally. They confirm that flooding in Ningi LGA is a recurring environmental hazard driven by both natural and human factors, and that GIS provides an effective tool for flood risk mapping and mitigation planning.

6. Proposed Mitigation Strategies

The study recommends a phased flood mitigation approach involving construction of peripheral canals, establishment of upstream earth dams, improvement of drainage systems, enforcement of land-use regulations, and integration of flood hazard maps into physical planning processes.

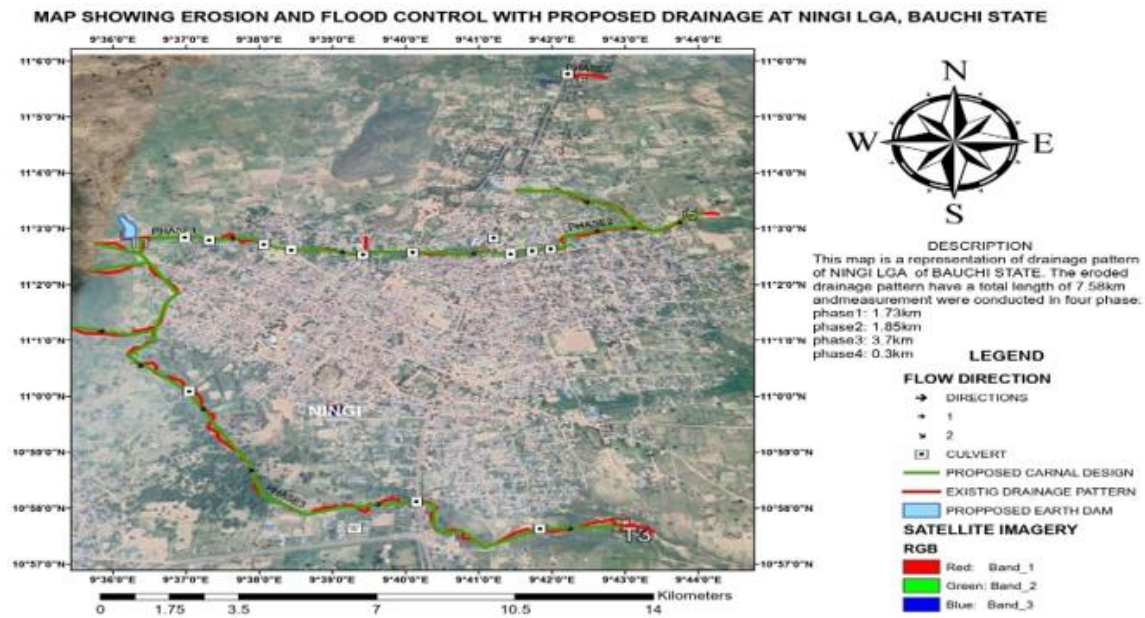


Figure 8 Flood Mitigation Strategies Using GIS

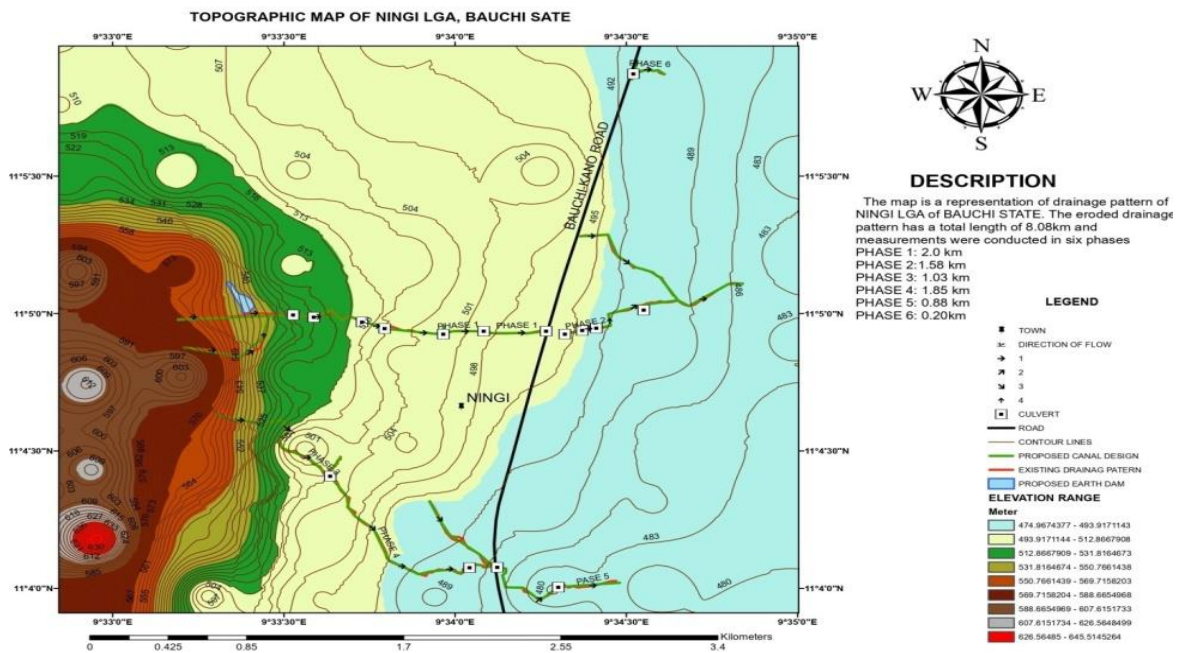


Figure 9: This Shows the representation of the Existing Direction of Flow and the Proposed Mitigation Measures Using the Topographic Map of the Study Area

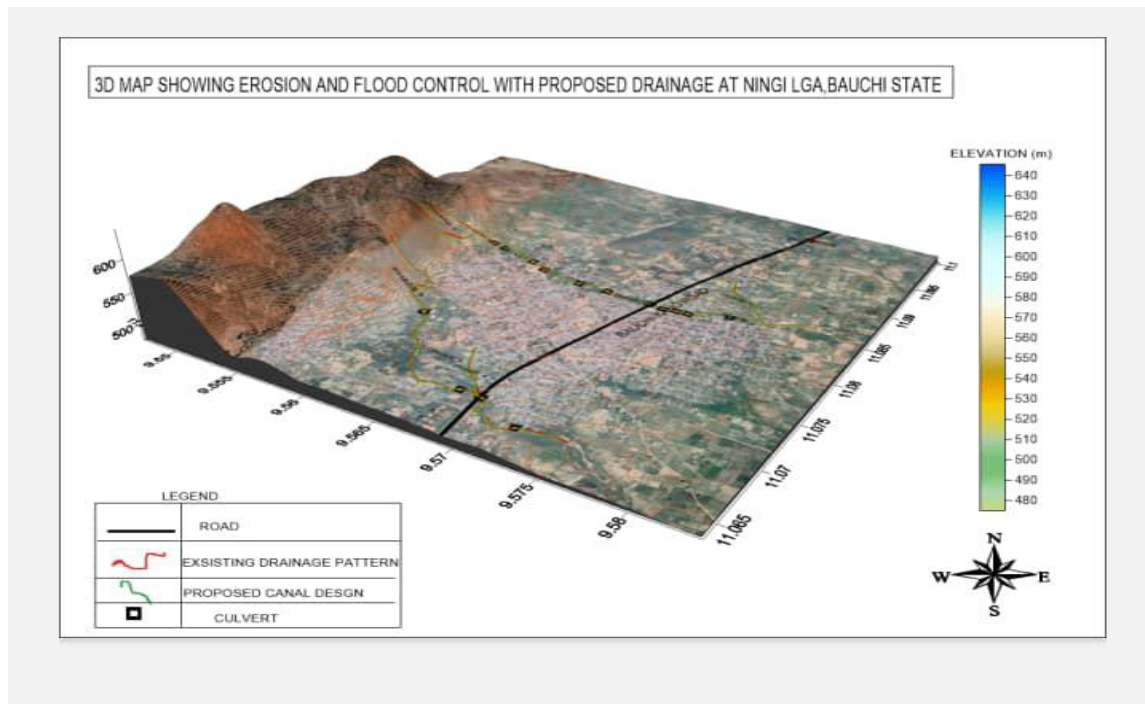


Figure 10: This Shows the Graphical Representation of the Existing Drainage Pattern and Proposed Canal Design using 3 Dimensional perspective

7. Conclusion

The study concludes that flooding in Ningi Local Government Area is a recurring environmental hazard influenced by both natural factors (rainfall, topography) and human activities (poor drainage, land use practices). GIS has proven to be a highly effective tool for identifying flood-prone areas, analyzing spatial patterns, and producing flood risk maps that support planning and decision-making.

The presence of large populations in high-risk zones highlights the urgent need for integrated flood management strategies. Without proper intervention, flooding will continue to cause significant socio-economic and environmental damage in the study area. Therefore, GIS-based flood risk mapping is essential for sustainable flood management and should be incorporated into local and state-level planning policies.

References

Aja, E. et al. (2024). Comprehensive GIS-based flood risk assessment for mitigation planning. *World Journal of Innovative Management and Technology*.

Alhaji, A. M. (2025). Geospatial analysis of the impacts of flood vulnerability on land use land cover changes in Bauchi metropolis. *Journal of Biodiversity and Environmental Research*, 7(4).

Federal Government of Nigeria (2022). National Flood Disaster Report.

International Organization for Migration (IOM). (2024). *Flood situation report: Bauchi State*.

Kafi, K. et al. (2026). Mapping the impacts of recurrent floods and windstorms in Bauchi metropolis. *Frontiers in Earth Science*.

Muhammad, B. I. (2024). Flood risk assessment and its implications on critical infrastructure in Nigeria. *Afropolitan Journals*.

Nguyen, T. H., Ricci, S., Fatras, C., et al. (2021). Improvement of flood extent representation with remote sensing data. *Hydrology Research*.