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Flood Risk Assessment and Its Implications on Critical Infrastructure Resilience in Nigeria

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Abstract

Flooding is one of the recurrent natural disasters in Nigeria that poses huge threats to not just people but also critical infrastructures. In 2024, the Federal Ministry of Water Resources and Sanitation and the Nigeria Hydrological Services Agency (NIHSA) identified 31 states including the FCT as high-risk areas for significant flood impacts. The impact of floods generally has caused devastating damage to critical infrastructures resulting from high rain intensities for a long duration. It becomes pertinent to evaluate the impact of floods on critical infrastructures like roads, bridges, residential buildings, water supply systems, and electricity facilities. Thus, this research seeks to explore the vulnerabilities and impacts of floods on critical infrastructure which is fundamental to economic growth, development, and coping mechanisms. A structured questionnaire was distributed among a sample of 90 including government department, construction industry, and community members to seek their views on the vulnerability risk of infrastructure and flood sources. Results indicate that most of the damages reported 42% were due to the destruction of roads and bridges, followed by residential houses at 31%. The main cause of flooding identified by 54% of respondents was poor drainage systems, while 31% cited poor waste management as a contributing issue. Hence, restoration of the drainage systems, implementation of prohibitions on encroachment of flood-prone areas and improvement of early warning systems are critical and pressing. The uniqueness of the study lies in its effort to address the gaps and challenges that exist in infrastructure resilience by identifying the most critical elements that are prone to risks and proposing mitigation measures against floods in the urban centers of Nigeria which are experiencing rapid growth.

Keywords: Flood Risk, Flood Risk Assessment, Flood Mitigation, Infrastructure Resilience, Nigeria.

Introduction

Coastal areas worldwide are increasingly endangered by the repercussions of global climate change, such as floods, and Nigeria is no different. The future possibility of coastal flooding presents considerable challenges to local infrastructure, livelihoods, and community well-being (Adewale et al., 2024). Flooding is a regular occurrence and a widespread natural environmental hazard in several geographical zones in Nigeria (Oyebode, 2021). It is the most commonly encountered natural hazard, especially in locations with water bodies such as oceans, seas, rivers, dams, lakes, streams and ponds Ladan (2019). Flooding appears to have significantly increased in recent decades due to deforestation, land-use change, population development, urbanization, inhabitation in the high slope zones, loss of wetlands, and climatological factors related to an increase in intense rainfall events (Bhat, Alam, Ahmad, Farooq, et al., 2019; Bhat, Alam, Ahmad, Kotlia, et al., 2019).

Critical Infrastructures, such as power grids, highways, trains, ports, airports, water systems, encompass the physical backbone of contemporary society. They are vital for the continuing supply of products and services, as well as ensuring economic and social well-being. Extreme occurrences such as floods pose major dangers to these critical infrastructures. Flooding damages metropolitan areas where various vital facilities are situated. Decisions on where to develop residences are increasingly acknowledged as a major instrument in controlling future flood risks and as such preserving vital infrastructure from flooding is of fundamental significance (Pant et al., 2016). Nigeria's growth has traditionally been impacted by its rivers, notably the Niger and Benue Rivers, which have played a significant role in the construction of numerous towns and infrastructures. The Atlantic Ocean, bordering Lagos State on the southern coast of Nigeria, has pushed the construction of key infrastructure in transportation, industry, and urban development. However, these rivers and coastal vicinity also bring considerable issues in the form of floods. Lagos State, for instance, is a low-lying coastal metropolis that is especially vulnerable to both coastal and interior floods. Roads and bridges, particularly those adjacent to the shore and flood zones, are at danger of inundation during major flooding events, which has substantial consequences for the status of key infrastructure.

Many of these floods may be traced back to human activities such as building along rivers, lack of suitable planning for large metropolitan areas, inadequate meteorological stations, and insufficient rainfall data in certain regions. According to Oyebode (2021), causes of floods in Nigeria include: the opening of dams surrounding rivers (75%), narrow stream or river channels (8%), indecent waste disposal (7%), excessive precipitation (6%), and inadequate drainage systems (4%). In Nigeria, flooding of cities has become an annual occurrence, especially during the prime time of the rainy season. The consequent damage caused by floods demands for a more realistic approach to flood management and control Oyebode et al., 2023. The research of Aderogba (2012) found that the floods in Lagos state are largely caused by Torrential rains (94.10%), filled/silted/dirty drainage channels (87.15%), Blocked Canals (97.55%), and insufficient drainage channels (94.30%). This emphasizes the relevance of water and waste-water systems infrastructure in mitigating flood occurrences.

The persistent occurrence of floods in Nigeria has posed a threat to the country's vital structures namely; causing disruption in transport systems, housing and economy in general. Although infrastructure service and maintenance are professional concerns, there is an increasing apprehension on the knowledge concerning the weaknesses in infrastructure systems and how certain mitigating actions maintenance, drainage improvement and enforcement work, tend to influence them. As these issues posed by ovation's floods in critical infrastructure and their potentials for managing resilience are the primary focus of this research. This study seeks to:

i. Identify infrastructure types most vulnerable to flood-related damage.
ii. Assess factors contributing to increased flood vulnerability, including drainage systems and waste management.
iii. Propose effective resilience strategies tailored to Nigeria's critical infrastructure needs.

To guide this investigation, the study addresses the following research questions:

i. Which types of critical infrastructure in Nigeria are most susceptible to flood-related damage?
ii. What specific factors, such as drainage quality and waste management, contribute to flood risks affecting critical infrastructure?
iii. How can targeted resilience strategies, such as maintenance practices and early warning systems, be implemented to mitigate flood impacts on essential infrastructure?

Literature Review

The federal highway from Kano to Maiduguri was significantly damaged by a heavy downpour, particularly between the Malori and Guskuri villages in the Katagum Local Government Area of Bauchi State. The dual carriageways were totally swept away, leaving motorists and pedestrians with little choice but to seek alternate routes (Aliyu, 2024). Also, more recently A portion of the Bauchi-Jigawa Road in Kwanar Babaldu, which is under the jurisdiction of the Dutse local government, was significantly damaged and disrupted by heavy inundation. This was due to a prolonged period of intense rainfall, which lasted about six hours. The affected road serves as a critical connection between four states – Kano, Jigawa, Bauchi, and Plateau necessitating that road users seek alternative routes. (TVC News, 2024).

The Ibadan floods on 26th August, 2011 was regarded as catastrophic, as the more than 6-hour rain of 187.50mm resulted to the death of over 100 people, damaging homes, automobiles, cemeteries and destroyed important infrastructures like as bridges, highways, and electrical poles (Sunday Tribune, 2011). In the months of July to September 2012, the country as a whole witnessed its worst flooding in five decades as floods affected about 27 states particularly those along the basins of rivers and streams extensive inundation of settlements and farmlands causing the death of 400 persons, and the displacement of about two million people from their homes (Babatolu, 2018). In July, August and September 2017 a total of 27 States were impacted some of the states include Kebbi, Benue, Lagos, Niger, Rivers and Abia. The floods caused the death of 46 persons and destroyed structures, residential properties and farmlands (NTA, 2017). Incidences like this underscore the devastating effect of floods on critical infrastructures. The report by UNDP-NBS-NEMA revealed that 2022 floods in Nigeria were much greater in rural regions (74%) compared to roughly 40% in urban areas. Out of the 6 states that received the greatest amount of flood, Jigawa state was most hit. A substantial percentage of respondents who participated in the poll stated that construction/cleaning of drainage should be put in place as a protective measure.

The study conducted by Pant et al. (2016) developed an integrated methodology for flood impact assessment of facilities. The models and research gave insights into understanding several elements of land use for flood risk management in key assets. This analysis indicated that of the essential infrastructures within the Thames basin in Great Britain, Wastewater treatment plants were at the highest danger of being harmed by flood since huge numbers of such assets are positioned immediately in flood zones, as predicted due to function. The least vital infrastructure impacted was airports. From the survey undertaken in the research by Ayog et al 2017 on Flood Risk Assessment on Selected Critical Infrastructure in Kota Marudu Town, Sabah, Malaysia it was revealed that as the flood depth grows, the effect of the flood progressively becomes critical. The transportation system faces the most severe effect, as transit access will be abandoned when the flood depth gets over 0.6 m. Research conducted by Ladan, 2019 on the Jiba flood tragedy in Katsina state found that the flood caused the entire destruction of 2 bridges and partial damage of other 2 bridges along the storm drainage. Electricity poles were brought down with wires trapped in the rubbles of fallen houses in several regions. Water pipes that flow into the stormwater drainage were damaged while other pipes were brought to the surface or exposed by the floodwaters. This demonstrates the devastating impact of floods on vital facilities.

Roman Schotten and Daniel Bachmann (2021) address the need for effective modeling techniques in assessing impacts of floods on critical infrastructure. They have developed a comprehensive model using ProMaIDes software that simulates risks of flooding and shows where essential services are vulnerable. The study identified both direct (e.g., infrastructure loss) and indirect (e.g., economic disruption) damages due to floods. Nonetheless, limitations were presented by lack of data among others especially as it only focused on specific types of infrastructures making one doubt about whether its findings can be generalized or not. Despite these challenges the study contributes significantly to flood risk management claiming that robust modeling should be applied in decision-making but urging more data accuracy improvements and wider analyses as further research avenues.

The floods normally bring about commercial, social and religious activities to stop as automobiles would have to crawl over flooded roads while people would wade through shoulder-high rain water whenever it is feasible at all. (Aderogba 2012). The absence of effective public infrastructure services in most areas has elevated the need for a sustainable flood control regime in public policy. Critical appraisal, disaster preparation, prevention, strategic planning, and the implementation of mitigation measures are important (Oyebode, 2021). Oyebode (2021) believes that contemporary technology, such as geographic information systems (GIS), might be implemented for sustainable building, erosion management, flood prevention, and infrastructure development. Moreover, frequent hazard assessment planning, notably in Lagos, the Niger Delta, and rainforest parts of Nigeria, is required. The finest materials and most modern structural engineering innovations must guarantee that water-retaining structures are appropriately protected against sliding, ground pressures, hydrostatic forces, and overturning moments (Oyebode 2022).

According to Ogunrayi et al. (2023), structures and subsidies built along the Ilaje coastline are likely to be washed away by changing coastal processes owing to the razor thin shoreline which is associated with low carrying capacity. The author also notes that eroding processes are more common in the middle part of the coast than at its western end indicating a dire concern for Ilaje's survival. Others contributing factors to climate change as well as anticipated sea level rise are flatness of the habitat and heavy sea waves. The authors' conclusion correspondingly agrees with past studies carried out by Dada et al. (2019), Badru et al. (2017), and Popoola (2022) who reported higher erosion rates on the middle part of shores. The most recent research conducted by Daramola et al. (2022) showed that the coastlines all over the area eroded by 95% or so between 2015 and 2019; the eastern part was particularly the hardest hit in terms of loss of land. This is in agreement with the findings of the study, indicating a shift in erosion dominance from the central part which has been previously more exposed to coastal hazards in recent times. According to Komolafe et al. (2021) who applied statistical methods using remote sensing and GIS tools on recent changes along Ilaje coastline in South-West Nigeria.

Rouhanizadeh et al. (2024) addressed socioeconomic vulnerability to severe floods using GIS and statistical modeling. The research used US Census Bureau statistics on age (31.3%), urbanization (21.5%), work status (13.7%), and education (12.1%) to show 78.6% variance in New Orleans social vulnerability. Thus, the social vulnerability index (SVI) was created by estimating and mapping social vulnerability and flood risk maps to create a complete map of exposures to vulnerable populations, helping managers identify high-risk areas in their jurisdictions. This research sheds light on how socioeconomic factors and flooding risks interact, emphasizing the need for targeted activities to increase disaster readiness and tenacity among disadvantaged groups and calling for more research to improve an evaluation scheme and make it more adaptable.

Prevention measures should include quality control and monitoring of civil engineering projects, notably on roads and drainages, as well as the execution of plans, construction of

frameworks, and enforcement of government laws and regulations (Oyebode, 2021). For example, the construction of comprehensive flood risk maps utilizing analytic hierarchy techniques and GIS, as done in Ilaje, Ondo State, may indicate various degrees of sensitivity to flooding across different locations, helping to prevent environmental damage. Ayog 2017 highlighted that flood challenges such as these would necessitate structurally and/or non-structurally fortifying the important infrastructures. Remote sensing and GIS methods have developed as key tools for detecting flood risk zones and developing flood susceptibility maps, delivering crucial insights for informed decision-making (Adewale 2024). Nkwunonwo (2020), noted that additional research are required to construct customized models that are capable of modeling flood inundation threats without much rely on scattered topography and friction information. Consequently, this project would apply GIS in mapping of flood risk zones and spatial studies to identify facilities prone to flooding using data analytic methodologies.
Flooding has displaced more people than any other natural catastrophe (World Bank, 2006). Flood risk is analyzed and separated into three categories: exposure, susceptibility, and flood hazard. On multiple instances, rivers in Nigeria, including the Kaduna River (2003), Elbe River (2003, 2005, and 2007), Sokoto River (2006), and Ogun River (2007), have exceeded their banks, drowning nearby houses on their floodplains. Consequently, flooding, a natural danger connected with floodplain developments, remains a key concern for Nigerian towns. Flood disasters in the past have exposed the necessity to secure infrastructure against catastrophic threats, driving the need for planning, response, and recovery strategies related with infrastructure safety. To be prepared to prevent and manage hazardous flood events, it is vital to identify and assess the susceptibility of key infrastructure and related structures (Ayog et al., 2017). Consequently, this article tries to examine the danger of floods on vital infrastructures in Nigeria.

Methodology

This study assessed the impact of flood on critical infrastructures on regions that experience frequent flooding in Nigeria. Primary data collection was carried out through a structured electronic questionnaire using Google Forms. The survey was aimed at specialists in relevant fields, including but not limited to engineers, surveyors, geologists, and infrastructure managers as well as the general public particularly those living in the flood-prone areas. The choice of these participants was to ensure different opinions about the damage caused by floods and the reasons behind it as well as the possible measures to curb floods. Accessing respondents who understand the implications of flooding having a direct relation was through a purposive sampling technique. This survey was conducted in 26 states of the country including the capital city of Nigeria with a total of 90 respondents. Sample size of 90 participants though small was found to be enough to get different opinions from different settlements.

The questionnaire was devised in a way where it contained sections on general questions on the problem, incidence, cause and effect of the flood, damage control, and alleviation measures. Recognizing that content validity is critical, the research instrument was developed through an extensive assessment of existing flood impact literature and studies on sustainable infrastructure. Pre-testing was carried out with some participants in the target group to improve the clarity and relevance of the questions. Descriptive statistics, including frequency distributions and percentages, were used to summarize responses on the frequency, severity, and impact of flooding. One-way ANOVA (Analysis of Variance) tests were also performed to analyze the differences in the perceptions of professionals and residents and establish whether the differences in perceptions were significant or not among respondents with different backgrounds. This statistical choice was made to facilitate a more meaningful comparison, which in turn, increases the quality of the findings.

Result and Discussion

Demographic Information

Out of the 36 states and 1 capital in Nigeria, 26 states including the capital city participate in the electronic based questionnaire with responses from states across all the 6 geo-political zones in Nigeria. These 26 states are part of the 31 high-risk flood areas identified by the Nigerian Hydrological Services Agency (NIHSA). The data as shown in Fig. 1 revealed fairness distribution across the country. The responses per state does reveal the overall extent of flooding in a particular state. However, It shows the impact and severity of flooding on critical infrastructures in Nigeria. Fig. 2 shows the distribution of the respondents based on years lived in a particular area. It can be seen that 54% of the respondents have lived for more than 10 years in their respective area of participation. These shows how acquainted the respondents are with the area of study. Fig. 3 shows often times the respondents experienced flooding. 34% of the respondent's experience flooding annually, which has a close margin to the respondents whom rarely experienced flooding with 27%, 22% of the respondents occasionally experience flooding, 12% had never experience flooding, and 5% with a bi-annual experienced of flooding.

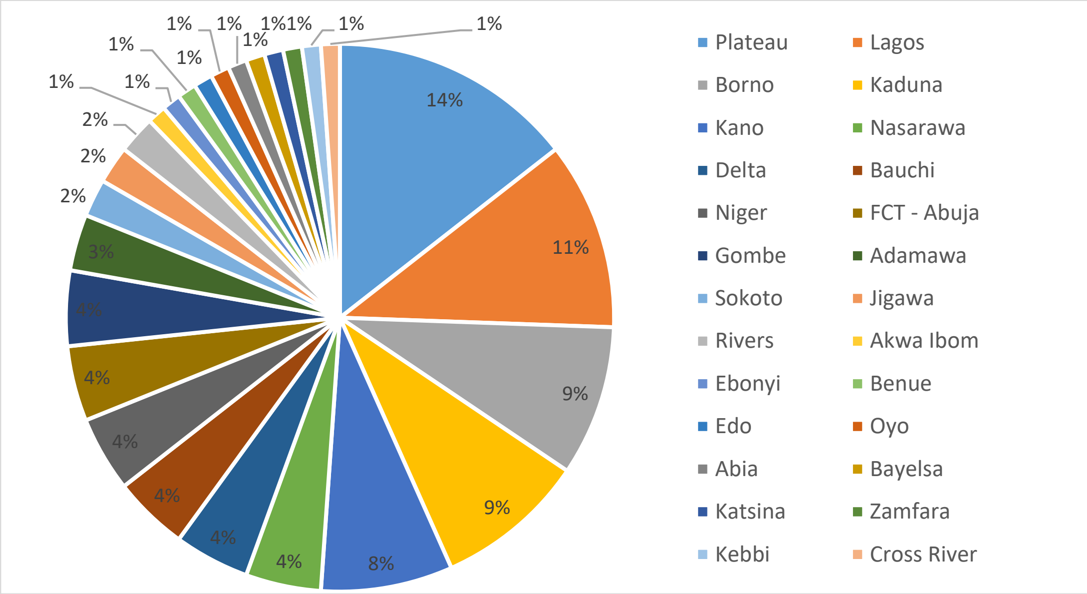

Figure 1. The distribution of respondents based on years lived in a certain area.
Source: *Authors Electronic based survey, 2024.*

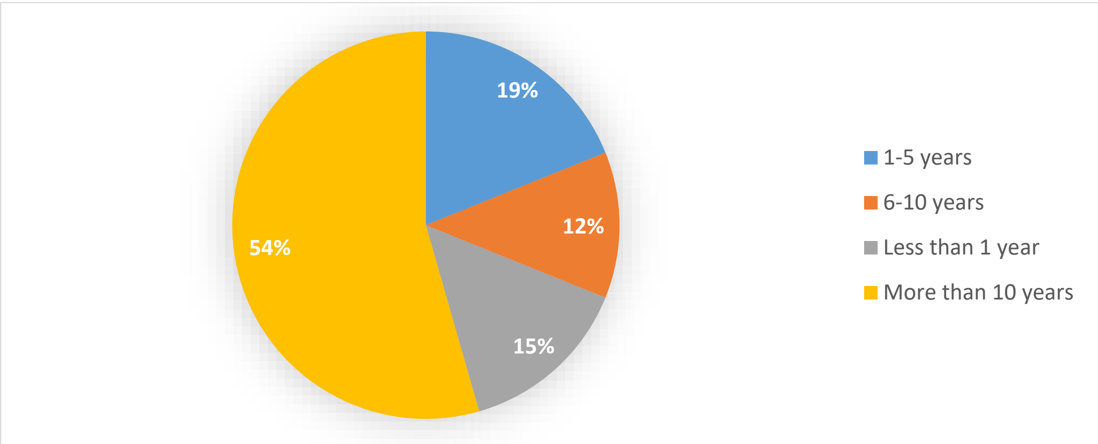

Figure 2. The distribution of respondents based on years lived in a certain area.
Source: *Authors Electronic based survey, 2024.*

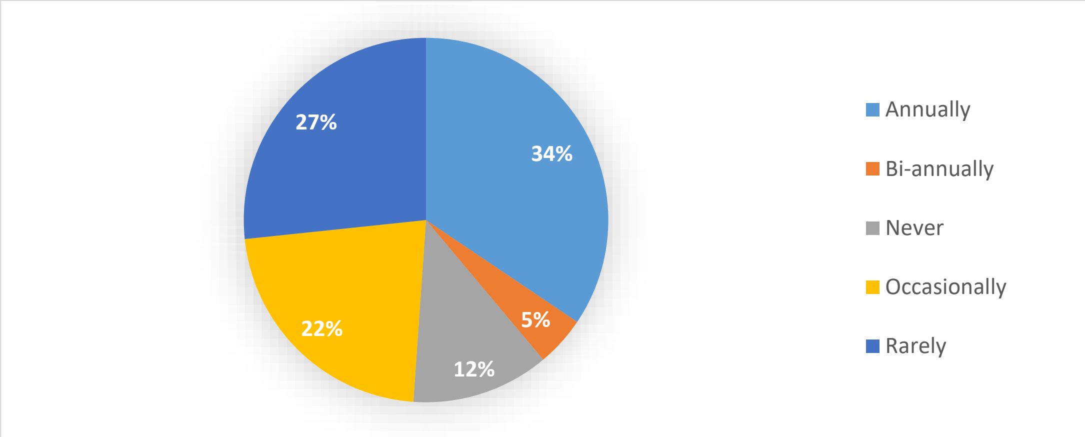

Figure 3. The distribution of respondents based on flooding experience times.
Source: *Authors Electronic based survey, 2024.*

Flood Impact on Critical Infrastructures

Fig. 4 shows the responses on affected critical infrastructures. Roads and bridges are the most affected critical infrastructure with 42% of the respondents, 31% residential buildings, 9% water and sanitation, 8% power supply, 3% schools and 2% others. These findings reflect that flood harm roads and bridges mostly. This is in line with their vital functions on transport. A high percentage (42%) shows the extent to which floods damage transport infrastructure disrupting economic activities or emergency services.

Other areas such as residential buildings that constitute 31 % of the affected infrastructure are also severely affected. Thus, it can be inferred that housing is substantially threatened by such floods together with peoples' lives in them. Destruction of homes displaces single persons and households thereby raising needs for temporary accommodation for them (in case they have nowhere else to go) as well as supporting materials which include food, clothing among others.

In addition, water supply and sanitation systems making up 9 % affected infrastructure demonstrate how maintaining clean water and proper sanitation becomes challenging during situations of flooding. These interruptions can lead to waterborne diseases and other public health crises, especially in densely populated areas. Power supply infrastructure is also a great cause of concern even though it is less affected than any other sector at 8%. Power breakdown can disrupt other critical infrastructures which include hospitals, communication networks as well as industrial processes worsening flood backdrops.

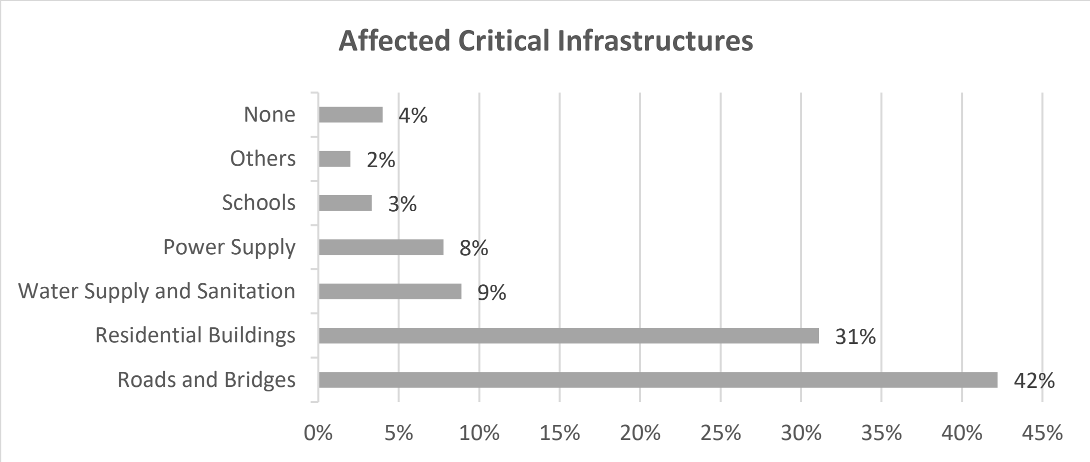

Figure 4. Responses on affected critical infrastructure.
Source: *Authors Electronic based survey, 2024.*

Fig. 5 shows the response on immediate impact on infrastructure after flooding. This is an integral part of this study which reveal the impact of the flood on infrastructure which is often temporary disruption, displacement of residents, permanent damage, loss of lives and increased/repair maintenance caused. The study shows that majority of the impact of floods on infrastructure is attributed to temporary disruption with 33% and displacements of residents with 28% of the respondents, 14% permanent damage, 11% loss of lives, 10% increased repair/maintenance cost and 3% with no impact on infrastructure. Temporary disruption of infrastructure can result to loss of lives in case of an emergency situation. It also implies that despite the fact that floods usually cause temporary breakdowns in essential services, eventually things can be normalized and thus these are addressed.
The impact of flood on critical infrastructure shows the necessity for immediate response in the case of flooding. As shown in Fig. 6, 43% of the repair efforts on these infrastructures is delayed and 18% are left unrepaired which poses risk to the structural health of the infrastructure and can potentially lead to damage. Thus, only 21% of the respondents revealed that there is an immediate repair effort on the affected infrastructure.

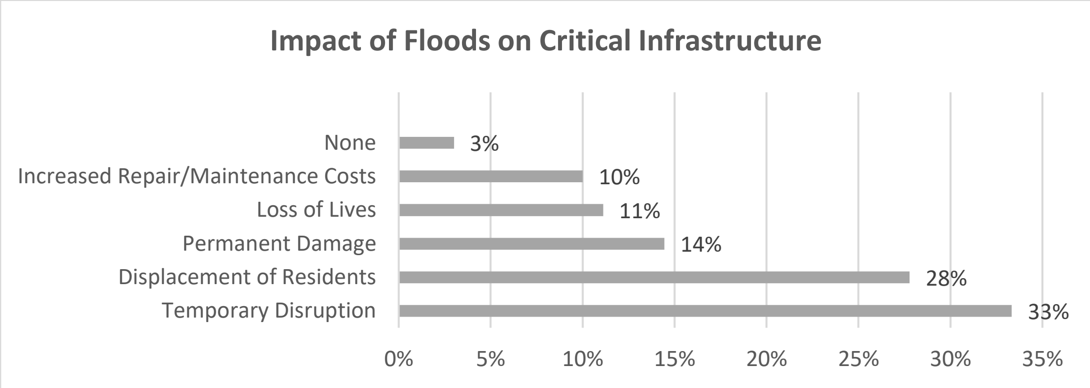

Figure 5. Response on impact of floods on critical infrastructure
Source: *Authors Electronic based survey, 2024.*

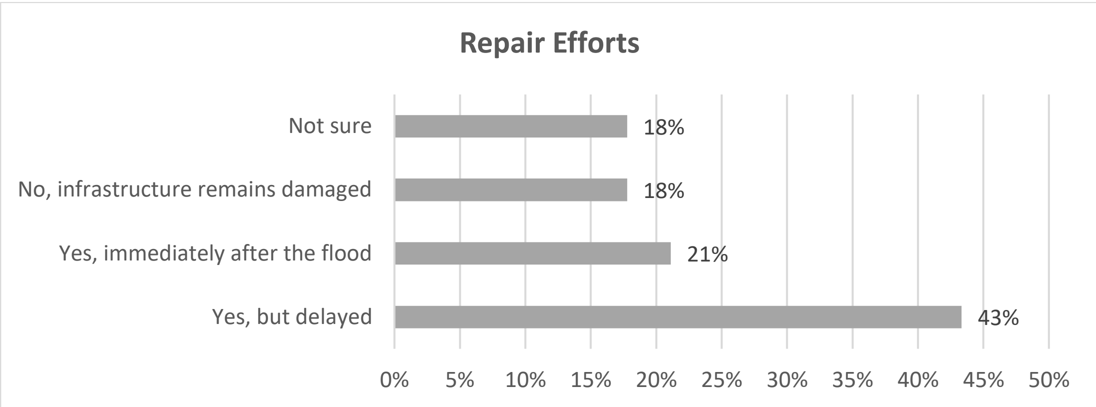

Figure 6. Response on repair efforts on critical infrastructure
Source: *Authors Electronic based survey, 2024.*

Overall, the rate at which temporary interruptions occur as the most direct effect conforms to the reality that restoration processes, despite being common, are frequently deferred. The consequence of this postponement worsens the temporary aspect of the disturbances and might lengthen their effects; hence floods may have wider social and economic consequences. The high number of respondents who asserted that infrastructure is still not repaired shows that there is a need for stronger and faster recovery plans so that lasting interruptions can be diminished and temporary impacts do not develop into more serious, lasting harm events.

Table 1: Main Causes of Floods in Nigeria

Major causes	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Poor Drainage System	54%	16%	4%	8%	18%
Over Population / Urbanization	24%	18%	13%	24%	20%
Deforestation	17%	26%	20%	20%	18%
Climate Change/Rising Sea Level	23%	23%	29%	12%	12%
Poor Waste Management	40%	20%	11%	11%	18%
Natural Topography	31%	26%	14%	14%	14%

Source: *Authors Electronic based survey, 2024.*

Table 2: Main Causes of Flood Analysis

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.6666667	5	0.133333	0.001156	1	2.6206541
Within Groups	2767.2	24	115.3			
Total	2767.8667	29				

Table 1 shows response on the main causes of floods in Nigeria. The data revealed that there are different factors that chiefly explain the flooding in Nigeria with poor drainage systems being the significant ones, as 54% strongly agree. This implies that the inadequacy or malfunction of drainage infrastructure is a major factor responsible for the frequent and severe flooding observed in different parts of the country. Where there are heavy rains and drainage systems are not enough to drain away excess water, then flooding occurs as a consequence of water accumulation even in both urban and rural areas.

Poor waste management is also cited as one of the reasons why flooding occurs with 40% of respondents strongly agreeing contributing significantly to it. More often than not, disposal of waste improperly causes clogged drains and water ways aggravating the risks of floods during raining seasons; this affects both urban and rural environments alike. Overpopulation, on its part has made things worse as 24 % of respondents strongly agree because increased population density puts extra burden on already existing infrastructures often leading them to failure during extreme weather events. Natural topography which 31% respondents strongly agree with also contributes especially in places where due to landscape gradients channelize rain water into populated zones making these places most prone to flooding.

Table 2 shows the analysis of the main causes of flood using ANOVA single factor test. As indicated by a significant F value, there is no meaningful distinction among the groups. Specifically, a p-value of 0.9999 is evidence for this conclusion, implying that under the null hypothesis the probability of observing what was actually observed is very high. It seems that personal variations within subjects have more effects than inter group variations which are considered as more systematic. In view of this one can observe that treatment or condition under examination has not had a statistically significant impact on any of the variables involved across different populations.

Figure 7. Visual Evidence of Flood Impacts in Nigeria
Source: *Online images of recent flooding in Borno State, Nigeria.*

Table 3: Effective Strategies for Mitigating Impact of Floods on Critical Infrastructures

Effective Strategies	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Improve Drainage Systems	63%	9%	4%	7%	17%
Urban Planning Laws	36%	33%	4%	13%	13%
Construction of Floods Defences	37%	30%	8%	10%	16%
Reforestation and Afforestation	20%	31%	27%	9%	13%
Regular Maintenance of Existing Infrastructures	36%	30%	14%	10%	10%
Enforcing Building Regulation	42%	24%	9%	13%	11%
Enhancing Early Warning Systems	49%	20%	8%	9%	14%

Source: Authors Electronic based survey, 2024.

Table 4: Effective Strategies for Mitigating Floods Impact Analysis

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.571429	6	0.095238	0.000401	1	2.445259395
Within Groups	6656.4	28	237.7286			
Total	6656.971	34				

Source: *Authors Electronic based survey, 2024.*

Table 3 shows response on the effective strategies for mitigating impact of floods on critical infrastructures. Respondents have generally pointed to enhancing drainage system as the most effective strategy for flood mitigation on critical infrastructure in Nigeria by a margin of 63% who strongly agree with it. This agrees with past findings that poor drainage is among major causes of flooding indicating there is need for better drainage infrastructure. To this end, 49% strongly agree on the need to improve early warning systems which give ample time for evacuation and protective measures. Similarly, 37% and 42% respondents strongly point out the importance of flood defenses construction and adherence to building codes respectively thus showing that these two are the major components of floods control through structure or regulation. In addition, urban planning laws as well as proper maintenance of existing infrastructures received 36% each showing how essential thorough urban planning is alongside keeping current systems updated. Also 31% respondents support reforestation and afforestation as means of controlling floods however this strategy appears to be seen as more of a complement than a leader. In a nutshell, stresses are on a multi-faceted approach which includes infrastructure improvements, law enforcement and environmental management as important elements in successfully managing this problem.

Table 4 shows the analysis of the effective strategies for mitigating impact of floods on critical infrastructures. As the P-value equals 1 and the F-value is considerably lower than the critical value, ANOVA shows that differences between groups are not significant in a statistical sense. Also, 6656.4 represents high sum of squares within groups while 237.73 signifies large mean square within groups stressing on this fact: most variability is found in the groups themselves rather than between them. This means that whatever factor we are testing does not really affect our response variable much; therefore, we have considerable unaccounted variance because it is not due to differences among groups.

Conclusion

The results from this research indicate grave weaknesses in Nigeria's critical infrastructures like roads, bridges, and housing, which suffer greatly from flooding activities. It shows how floods impair service delivery, force people out of their homes, and negatively impact the overall economy, therefore calling for swift actions in areas that are prone to flooding. While, factors like bad drainage systems, high population density, poor refuse disposal systems, and natural landscape relief play a major role in causing floods, it is apparent that there is need to implement better urban design and stronger infrastructure systems. In spite of this, certain limitations are present in other parts of the article. The small size of the sample, and its concentration on certain areas, may inhibit the applicability of the findings to all the flood affected regions of Nigeria. The policy ramifications of this research point to the importance of making specific investments in flood-resilient infrastructure such as strengthened pavements, better drainage systems, and building of embankments. The development of sophisticated early warning systems and strict building codes, and considering flood risk in development plans are all very important measures.

Recommendations

1. Further research may attempt to cover other geographical areas and use bigger samples in order to establish a more meaningful perspective on the issue of resilience of infrastructure.
2. Build and rehabilitate drainage systems that will prevent water-loggings and contain more rainfall. Regular maintenance should be conducted in order to ensure they serve their purpose effectively.
3. Enforce flood resistant building materials on flood prone areas by using very strict building codes that mandate elevation of all structures at both new site levels and within surrounding neighborhoods.
4. Enhance early warning systems with new technologies while creating public awareness through education on flood preparedness and evacuation programs.
5. Improve maintenance of transportation systems and repair efforts post floods.

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Data Availability: The dataset that supports the findings of this study is available from the corresponding authors upon request.

Declarations

Conflicts of interest: The authors declare that they have no competing interests.

Ethical approval: This study article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent: Formal consent is not required for this type of study.

References

Aderogba, K. A. (2012). Global warming and challenges of floods in Lagos metropolis, Nigeria. *Academic Research International, 2*(1), 448–468.

Adewale, B., Zhang, X., Wang, R., Adenugba, O., & Adewusi, A. (2024). An integrated multi-criterion decision-making approach for flood vulnerability assessment: A case study in Ilaje coastal city, Ondo State transgressive mud coast, Nigeria.

Aliyu, H. (2024, August 9). Flood cuts off Kano-Maiduguri highway, Gov Mohammed seeks FG's intervention. *Channels TV*. https://www.channelstv.com/2024/08/09/flood-cuts-off-kano-maiduguri-highway-gov-mohammed-seeks-fgs-intervention/

Ayog, J., Tongkul, F., Mirasa, A., Roslee, R., & Dullah, S. (2017). Flood risk assessment on selected critical infrastructure in Kota Marudu town, Sabah, Malaysia. *MATEC Web of Conferences, 103*, 04019. https://doi.org/10.1051/matecconf/20171030

Badru, G., Odunuga, S., Omojola, A., & Oladipo, E. (2017). Shoreline change analysis in parts of the barrier–lagoon and mud sections of Nigeria coast. *Journal of Extreme Events, 4*(04), 1850004.

Bhat, M. S., Alam, A., Ahmad, B., Kotlia, B. S., Farooq, H., Taloor, A. K., & Ahmad, S. (2019). Flood frequency analysis of river Jhelum in Kashmir basin. *Quaternary International, 507*, 288–294.

Bhat, M. S., Alam, A., Ahmad, S., Farooq, H., & Ahmad, B. (2019). Flood hazard assessment of upper Jhelum basin using morphometric parameters. *Environmental Earth Sciences, 78*, 1–17.

Dada, O. A., Agbaje, A. O., Adesina, R. B., & Asiwaju-Bello, Y. A. (2019). Effect of coastal land use change on coastline dynamics along the Nigerian transgressive Mahin mud coast. *Ocean & Coastal Management, 168*, 251–264.

Daramola, S., Li, H., Omonigbehin, O., Faruwa, A., & Gong, Z. (2022). Recent retreat and flood dominant areas along the muddy Mahin coastline of Ilaje, Nigeria. *Regional Studies in Marine Science, 52*, 102272. https://doi.org/10.1016/j.rsma.2022.102272

Flood washes away part of Bauchi-Jigawa road in Jigawa State. (2024, August 12). *TVC News*. https://www.tvcnews.tv/2024/08/flood-washes-away-part-of-bauchi-jigawa-road-in-jigawa-state

Komolafe, A. A., Apalara, P. A., Ibitoye, M. O., Adebola, A. O., Olorunfemi, I. E., & Diallo, I. (2021). Spatio-temporal analysis of shoreline positional change of Ondo State coastline using remote sensing and GIS: A case study of Ilaje coastline at Ondo State in Nigeria. *Earth Systems and Environment*, 1–13.

Ladan, S. I. (2019, October 13–17). An empirical assessment of flood disaster in Nigeria: A case study of Jibia flood disaster Katsina state [Paper presentation]. *Association of Nigerian Geographers Annual Conference*, Kaduna, Nigeria.

Nigerian Television Authority (NTA). (2017, September 16). Floods across states of the federal [Television broadcast]. *Weekend File*, 9:00–10:00 p.m.

National Bureau of Statistics, National Emergency Management Agency, & United Nations Development Programme. (2023). *Nigeria impact of flood, recovery and mitigation assessment report 2022–2023: Final report*. Abuja, Nigeria.

Nkwunonwo, U. C., Whitworth, M., & Baily, B. (2020). A review of the current status of flood modelling for urban flood risk management in developing countries. *Scientific African, 7*. https://doi.org/10.1016/j.sciaf.2020.e00269

Ogunrayi, O. A., Mattah, P. A. D., Folorunsho, R., Jolaiya, E., & Ikuomola, O. J. (2023). A spatial temporal analysis of shoreline changes in the Ilaje coastal area of Ondo State, Nigeria. *Journal of Marine Science and Engineering, 12*(1), 18.

Oyebode, O. J. (2022). Design of water retaining structures and application of environmental engineering for sustainable environment. In O. Ayeni, O. Oladokun, & O. D. Orodu (Eds.), *Advanced* *manufacturing in biological, petroleum, and nanotechnology processing* (pp. 287–299). Springer, Cham.

Oyebode, O., & Paul, F. (2021). Flood mitigation and pollution abatement in Kaduna metropolis through engineering assessment and analytical hierarchy process design. *Nature Environment and Pollution Technology, 22*(2), 789–801. https://doi.org/10.46488/NEPT.2023.v22i02.021

Oyebode, O. (2021). Hazard assessment and implementation strategies for mitigating flood and erosion in Nigeria. *IOP Conference Series: Materials Science and Engineering, 1036*, 012066. https://doi.org/10.1088/1757-899X/1036/1/012066

Pant, R., Thacker, S., Hall, J., Alderson, D., & Barr, S. (2018). Critical infrastructure impact assessment due to flood exposure. *Journal of Flood Risk Management, 11*, 22–23. https://doi.org/10.1111/jfr3.12288

Popoola, O. (2022). Spatio-temporal assessment of shoreline changes and management of the transgressive mud coast, Nigeria. *European Scientific Journal, 18*, 20–99.

Rouhanizadeh, B., Safapour, E., & Silwal, A. (2024). A GIS-based social vulnerability assessment of communities in coastal areas exposed to extreme flood events: A case study of New Orleans urban area. *Construction Research Congress*. https://doi.org/10.1061/9780784485279.061

Schotten, R., & Bachmann, D. (2021). Conceptualization of a critical infrastructure network model for flood risk assessments. Hochschule Magdeburg. Retrieved from https://www.researchgate.net/publication/351230230

Sunday Tribune. (2011, August 12). Hundreds dead in Ibadan floods. *Sunday Tribune*.

World Bank. (2006). *Mainstreaming hazard risk management in poverty reduction strategies: A strategic framework for action.* Discussion paper.