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Assessing Natural Disaster and Sustainable Infrastructure development: A Case Study of Flood Resilience and Mitigation Strategies in Maiduguri Nigeria.

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ABSTRACT: Natural disasters, such as floods, are increasing in frequency and intensity due to climate change, especially in regions like Maiduguri, Nigeria. Maiduguri, located along the Ngadda River, frequently experiences seasonal flooding that severely impacts its infrastructure, economy, and population. The city's low-lying geography and inadequate drainage systems have left it particularly vulnerable. Recent floods have caused widespread damage, including the collapse of bridges, isolating communities and hampering rescue efforts. The economic losses are estimated to exceed $100 million, emphasizing the urgent need for improved flood resilience. This paper explores the current flood risks and infrastructure challenges in Maiduguri and proposes sustainable flood resilience strategies, such as upgrading drainage systems, enhancing early warning systems, and implementing green infrastructure. While progress has been made, particularly through pilot green infrastructure projects, challenges remain in funding, policy enforcement, and coordination among government agencies. Recommendations include a holistic approach combining structural and non-structural measures, public education, stricter land-use regulations, and international partnerships to build long-term flood resilience. These strategies offer valuable insights into addressing the rising flood risks and ensuring sustainable development in Maiduguri

KEYWORDS: Natural Disaster, Risk Assessment, Infrastructure and community Sustainable Development.

I. INTRODUCTION

Natural disasters are defined as severe and extreme weather and climate events that occur naturally in all parts of the world (UNDRR, n.d). These events can vary greatly in their nature, intensity, and frequency, often influenced by geographical location, climate patterns, and increasingly, by anthropogenic climate change (Rana, 2020). The United Nations Office for Disaster Risk Reduction (UNDRR) categorizes natural hazards into geophysical, hydrological, climatological, meteorological, and biological events (UNDRR, n.d). The frequency and intensity of natural disasters have shown an alarming increase in recent decades. In Nigeria, flooding stands as the most prevalent natural disaster. A growing number of Nigerian states face yearly inundations during rainy periods, attributed to climate change-induced rainfall increases (Aja and Olaore, 2014). Unlike certain natural calamities, flood control through rainfall management is feasible with proper planning and essential infrastructure (Agbonkhese et al., 2014; Dodman et al., 2012). Maiduguri State, located in northeastern Nigeria, has been grappling with increasingly severe flooding events in recent years. These floods have exposed the vulnerabilities in the region's infrastructure and highlighted the urgent need for sustainable development strategies. Thispaper examines the current state of flood resilience in Maiduguri State and proposes sustainable infrastructure solutions to mitigate future risks.

Background on flooding in Maiduguri State

Maiduguri, the capital city of Borno State, is a vital hub for political, economic, and cultural activities in northeastern Nigeria. Situated along the Ngadda River, the city frequently experiences seasonal flooding, which significantly challenges its infrastructure and economy. Historically, Maiduguri has been a center of trade, especially during the height of the Kanem-Bornu Empire, and has evolved into a diverse and economically

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significant city (Falola & Heaton, 2008). However, recurrent flooding, exacerbated by poor drainage systems and climate change, remains a major concern for sustainable development in Maiduguri. Seasonal floods disrupt agricultural activities, which form the backbone of the local economy, and often cause significant damage to infrastructure and private property (Khayyam, 2020). Flooding is particularly severe due to the city's low-lying geography near the Ngadda River, making the need for robust flood control systems critical. In response to these challenges, efforts have been made to improve Maiduguri's flood resilience through sustainable infrastructure development. This includes constructing embankments and improving drainage networks to manage water flow during the rainy season (UN-Habitat, 2022). Moreover, community-based flood warning systems and investments in flood-resistant housing are vital to protecting vulnerable populations. These strategies aim to secure the city's long-term growth and reduce the financial burden caused by recurring floods (NEMA, 2021).

Current Flood Risks and Infrastructure in Maiduguri

According to recent reports from the Borno State Emergency Management Agency (SEMA), the flooding event on September 10, 2024, caused by the Alau Dam's overflow, had catastrophic consequences for Maiduguri and its surrounding areas. The disaster affected over 400,000 individuals, resulting in at least 37 fatalities and 58 injuries. Dr. Amina Zanna, Director of SEMA, emphasized the severity of the situation, stating, "This flood event has overwhelmed our emergency response capabilities and exposed the vulnerabilities in our infrastructure." Dr. Abubakar Hassan, a hydrologist at the University of Maiduguri, explains the gravity of the situation when he opined that "The increasing frequency and intensity of floods in Maiduguri State are overwhelming our current infrastructure. Many of our drainage systems were designed based on historical data that no longer reflects our current climate reality." Furthermore, a post-disaster assessment conducted by the Nigeria Hydrological Services Agency (NIHSA) revealed that critical infrastructure suffered significant damage. Two major bridges in Maiduguri partially collapsed, effectively isolating several communities and restricting access to essential services. The NIHSA report highlights that "The partial failure of these bridges has not only hampered rescue efforts but also cut off access to healthcare facilities and markets for thousands of residents, exacerbating the humanitarian crisis." The economic impact of this disaster is expected to be severe. The World Bank estimates that flooding in Maiduguri State resulted in average annual losses of approximately $50 million between 2018 and 2022. Preliminary estimates from the Borno State Ministry of Economic Planning suggest that the direct and indirect costs of the flooding could exceed $100 million. The numbers of internally displaced persons (IDPs) who registered in one of some 30 camps increased to close to 400,000 people within a week. At least 18 of these camps were schools, which contributed to the government's decision to close some of the camps within a week's time, to enable reopening of schools in late September. These figures underscore the urgent need for improved flood resilience strategies and infrastructure upgrades in Maiduguri and the surrounding regions.

Casualties and displaced persons

Category	Count
Deaths	37
Injuries	58
Internally displaced persons	400,000

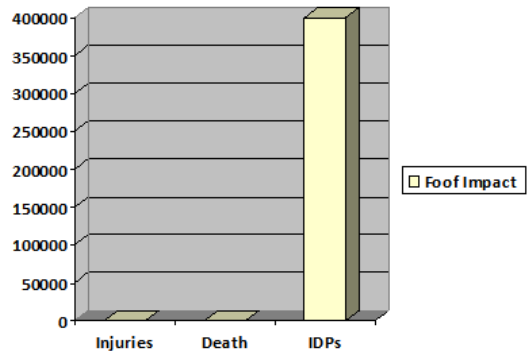

Fig. 1. Impact of Maiduguri Flooding that occurred on 10th September 2024

Total camps = 18 (schools) + 12 (other camps) = 30 camps.
Percentage for Schools used as camps:
(18/30) × 100 = 60%

Percentage for Other camps:
(12/30) ×100 = 40%

Resulting Percentages:
Schools used as camps = 60%
Other camps = 40%

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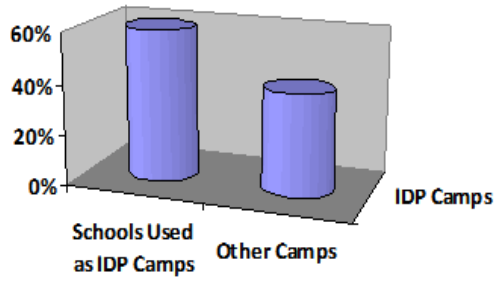

Fig 2. Distribution of IDP Camps in Maiduguri

Sustainable Flood Resilience Strategies

To address the flooding challenges in Maiduguri State, an approach combining structural measures, non-structural interventions, and green infrastructure solutions is necessary.

Structural Measures: Improving the city's drainage systems is a critical first step. Engineer Fatima Aliyu, from the Borno State Ministry of Environment, emphasizes the importance of upgrading existing infrastructure when he said that "We need to redesign our drainage networks to accommodate increased water volumes. This includes widening channels, installing pumping stations, and creating more efficient water diversion systems." Recent successful implementations of similar strategies can be observed in cities like Dar es Salaam, Tanzania. There, the World Bank-funded Tanzania Urban Resilience Program (TURP) has shown promising results, reducing flood-prone areas by 30% through infrastructure upgrades.

Non-Structural Measures**:** The Nigerian Meteorological Agency (NiMet) has recently launched a pilot program for an AI-driven early warning system in Maiduguri. Initial results show a 40% improvement in flood prediction accuracy, allowing for more timely evacuations and emergency responses. According to a study by Khodadad et al. (2023), implementing a robust early warning system can significantly reduce the loss of life and property during flood events. In addition to this, smart land-use planning that restricts development in flood-prone areas is essential for long-term resilience.

Green Infrastructure Solutions:Incorporating nature-based solutions into urban planning can provide multiple benefits for flood resilience. Professor Chidi Onwuka, an environmental scientist at the University of Nigeria, Nsukka, advocates for green infrastructure. He points out that "Urban green spaces, permeable surfaces, and restored wetlands can significantly reduce runoff and alleviate pressure on drainage systems. These solutions not only help with flood management but also improve the overall quality of life for residents. A recent study by the African Development Bank also found that cities implementing green infrastructure solutions experienced a 15-20% reduction in flood-related damages compared to those relying solely on traditional green infrastructure.

Implementation, Challenges and Opportunities

Despite the clear benefits of sustainable flood resilience strategies, implementation faces several challenges in Maiduguri State. The financial challenges are evident in Governor Babagana Zulum's recent supplementary budget request of ₦61 billion (around $80 million) to address flood damage. This comes after a total 2024 budget of ₦358.7 billion, revealing a shortfall between available resources and urgent disaster-related needs. The estimated $200 million needed for complete flood resilience improvements highlights the insufficiency of present funding levels. Institutional barriers also pose significant challenges. Dr. Amina Yusuf, a policy analyst at the Nigerian Institute of Social and Economic Research (NISER), points out: "There's often a lack of coordination between different government agencies responsible for flood management. We need a more integrated approach that brings together urban planning, water resources management, and disaster response under a unified strategy." However, these challenges also present opportunities for innovation and collaboration. International partnerships, such as the recently announced Nigeria Urban Resilience Project (NURP) supported by the World Bank, offer promising avenues for funding and technical assistance. This $200 million project aims to improve urban resilience in several Nigerian cities, including Maiduguri, through a combination of infrastructure upgrades and capacity building initiatives.

Sustainable Infrastructure Development Initiatives

Green Infrastructure: This is a network of natural and semi-natural systems designed to manage water, reduce flood risks, and improve environmental quality by mimicking natural processes. Instead of relying solely on traditional, engineered infrastructure (like concrete drains or flood barriers), green infrastructure uses vegetation, soils, and other elements that naturally manage water and create more sustainable urban environments. Some pilot projects have been started, including:

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- Restoring Urban Wetlands: two areas, totaling 15hectares, have been restored, increasing the ability to hold floodwater by about 50,000 cubic meters. Data shows these wetlands reduced flood depths by 20 cm during smaller floods.
- Permeable Pavement: In 15% of new roads in certain areas, materials that allow water to pass through are being used, covering around 12 km. This has reduced stormwater runoff by 30% compared to regular road surfaces.
- Rooftop Rainwater Collection: 10% of households in flood-prone areas have adopted these systems, which can hold up to 500,000 liters of water during heavy rain, easing the pressure on the drainage systems.

Resilient Building Practices: refer to construction methods and design strategies that enhance a building's ability to withstand and recover from natural disasters, environmental stressors, and other adverse conditions. These practices aim to reduce the damage caused by floods, storms, earthquakes, and other hazards, ensuring that buildings remain safe, functional, and durable in the face of extreme events. New building rules encourage flood-resistant designs, but adoption is still low:

- 30% of new buildings in flood-prone areas now follow these resilient designs, a rise from 10% in 2020. These structures experience 40% less damage during floods than traditional buildings.
- Only 5% of vulnerable existing buildings have been retrofitted, but those that have been upgraded showed 25% less damage in the 2022 floods.

These initiatives offer a clear view of the current state of flood resilience and infrastructure development in Maiduguri. While there has been notable progress, especially with early warning systems and green infrastructure projects, challenges remain. These include the fast-growing flood-prone areas, limited infrastructure coverage, and weak policy enforcement. Mixed reactions from stakeholders show the complexity of flood resilience, and while sustainable, green solutions seem promising, their slow adoption and small scale suggest a need for faster and broader implementation to tackle the rising flood risks effectively.

II. RECOMMENDATIONS AND CONCLUSION

The flooding challenges faced by Maiduguri State require urgent and comprehensive action. By implementing a combination of structural improvements, non-structural measures, and green infrastructure solutions, the region can significantly enhance its flood resilience. Key recommendations include:

1. Upgrading and expanding drainage infrastructure is crucial for effective flood management. This involves not only repairing and maintaining existing systems but also implementing new, more efficient solutions. Nature-based solutions, such as constructing wetlands, bioswales, and rain gardens, can complement traditional infrastructure. These green approaches mimic natural water cycles, absorbing and filtering runoff while providing additional benefits like improved air quality and enhanced biodiversity. By prioritizing such measures, communities can create more sustainable and resilient urban environments that are better equipped to handle heavy rainfall and reduce flood risks.
2. An early warning system is vital for protecting lives and property during flood events. However, simply having a system in place is not enough; it must be continually refined and improved to ensure its effectiveness. This includes leveraging the latest technologies, such as advanced weather modeling and real-time data analytics, to increase the accuracy and lead time of flood predictions. Equally important is ensuring that warnings reach all segments of the population, including vulnerable groups like the elderly, disabled, and those in remote areas. This may involve using multiple communication channels, including mobile alerts, sirens, and door-to-door notifications, as well as providing information in various languages and formats to overcome barriers to access.
3. Stricter land-use regulations are essential for preventing future development in high-risk flood zones. This involves creating and enforcing comprehensive zoning laws that restrict construction in flood-prone areas and require flood-resistant design features for any permitted development. Such regulations should be based on up-to-date flood risk assessments that consider climate change projections. Additionally, these policies may include incentives for relocating existing structures out of high-risk areas and promoting development in safer locations. While potentially controversial, these measures are crucial for long-term flood risk reduction and community resilience.

4. Public education programs play a vital role in improving community preparedness and response to flood events. These initiatives should go beyond simply providing information and focus on building practical skills and fostering a culture of preparedness. This could include organizing regular community drills, offering workshops on creating household emergency plans, and providing training on flood-specific first aid and rescue techniques. Education efforts should also address the importance of individual actions in flood prevention, such as proper waste disposal and maintenance of private drainage systems. By empowering residents with knowledge and skills, communities can significantly enhance their collective ability to cope with and recover from flood events.
5. Seeking international partnerships and funding opportunities is crucial for overcoming financial constraints that often hinder comprehensive flood management efforts, particularly in developing countries or economically challenged regions. This approach involves actively engaging with international organizations, NGOs, and foreign governments to access technical expertise, financial resources, and best practices in flood resilience. Potential avenues include applying for grants from global climate funds, participating in knowledge-sharing networks, and forming partnerships for joint research and pilot projects. By leveraging these international resources, communities can accelerate their progress in implementing robust flood management strategies and adapting to changing climate conditions.

III. CONCLUSION

In conclusion, these recommendations form a holistic approach to flood management that addresses both immediate needs and long-term resilience. By combining infrastructure improvements, early warning systems, land-use planning, public education, and international collaboration, communities can significantly reduce their vulnerability to floods and build a more sustainable future. However, successful implementation will require sustained commitment, cross-sector cooperation, and adaptive management to respond to evolving challenges and opportunities in flood risk reduction.

As climate change continues to pose unprecedented challenges, the actions taken in Maiduguri State can serve as a model for other flood-prone regions in Nigeria and beyond. By embracing sustainable infrastructure development, Maiduguri can build a more resilient future for its citizens and protect its economic growth in the face of increasing natural disasters.

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