Original Research Article

Resilient Infrastructure as a Panacea to Flooding in Nigeria

ABSTRACT

Flooding is a disaster which may occur naturally or as a result of human activities. Flooding which is a global hazard has resulted in devastating effects on humans and the environment. Thousands of lives and properties worth millions of dollars are lost annually as a result of flooding in Nigeria. Various Flood Risk Management (FRM) approaches have been employed to manage this menace in Nigeria resulting in little success. This paper highlights the types, causes and impact of flooding in Nigeria. It also evaluates Nigeria's FRM approach – the performance and lapses. It further reviews infrastructure resilience and advocates it as a formidable approach for Nigeria's FRM and makes recommendations for possible consideration and implementation of infrastructure resilience.

Keywords: Flooding, Flood Risk Management, Infrastructure Resilience, Nigeria

INTRODUCTION

Nigeria has a climate range from semi-arid in the north to humid in the south, characterized by distinct wet and dry seasons, and the length of rainy season varying between three to ten months from the northeast to the south of the country. Nigeria has a mean annual rainfall estimated at 1,150 mm, with about 1,000 mm in the central area, 500 mm in the north, and about 3,500 mm along the coast. Almost the entire country is exposed to one or more natural hazards. Floods usually affect communities along the major drainage basins and their tributaries, but flash floods can impact any region following extreme rainfall [1].
With the soaring national population and the need for shelter, the availability of land for building and infrastructure is becoming a matter of great concern in urban areas. According to the World Cities Report (2016), about 1 billion houses will be needed worldwide by year 2025. It also states that 30% of the urban population in developing countries reside in slums. Nigeria has an annual population growth rate of 2.5%, with a rapid urban population growth rate of 4.5% and slow rural population growth rate of 1.4% indicating a high rate of rural-urban migration. With increased and rapid urbanization of Nigeria, the landscape of flood prone communities and assets are on the increase [2-6].

The International Code Council [7] defines flooding as a general or temporary condition of partial or complete inundation of normally dry land from the overflow of inland or tidal waters, or the unusual and rapid accumulation or runoff of surface water from any source. Flooding is a disaster that usually occurs naturally or as caused by human activities, resulting in harm to humans and the environment. Flooding is one environmental problem that occurs regionally, nationally and globally. It occurs in various ways and conditions such as changes in atmospheric conditions, rainfall variations, continental drift, moderate to severe winds over water, unusual high tides, tsunamis due to undersea earthquakes, breaks or failures of dams, levees, retention ponds or lakes, or other infrastructure that retains surface water can influence the occurrence of flood.

Nigeria's flooding is majorly as a result of anthropogenic factors. Several human activities such as deforestation, indiscriminate dumping of refuse in drains, unregulated urbanization, inadequate to non-existent environmental infrastructure, weakness in institutional capacity and coordination, early warning systems and public awareness, weak implementation of planning laws and corruption have been observed to cause flooding in Nigeria [8-11].

Disasters when they occur usually result in pains and huge losses to the economy and in most cases; it is always difficult to quantify the actual cost of damages and recovery [12]. Flooding across the globe has resulted in massive loss of lives as well as huge socio-economic losses. According to the Global Facility for Disaster Risk Reduction (GFDRR), in the past 20 years, natural disasters have affected 4.4 billion people,

claimed 1.3 million lives, and caused $2 trillion in economic losses. It also states that, in the last 30 years, over 80 percent of the total life years lost in disasters came from low- and middle-income countries, typically setting back national economies by 5 to 120 percent of gross domestic product (GDP). There is evidence that disasters' impact on GDP is 20 times higher in developing countries than in industrial nations. As the scale, frequency, and severity of natural hazards continue to rise, so will future expected losses in the built environment. The annual losses resulting from disasters such as earthquakes, tsunamis, cyclones, and flooding are expected to increase from roughly $300 billion to $415 billion by 2030 [3].

Flooding in Nigeria has resulted in enormous devastation both to lives and properties, with the 2012 and 2022 flooding events been the most devastating in recent history. Accurate data on the impacts of flooding in Nigeria are inconsistent as the flooding impacts are poorly documented [11]. Flooding in Nigeria affects and displaces more people than any other disaster; it also causes more damage to properties. At least 20 per cent of the population is at risk from one form of flooding or another [13]. The Centre for Human Security of the Olusegun Obasanjo Presidential Library Foundation14 and the UN Office for the Coordination of Humanitarian Affairs15 in their 2012 flood reports revealed that in the 2012 floods in Nigeria, 2.3 million people were displaced from their homes; 363 human lives were lost; 16 million people in 108 local government areas were adversely affected; 600 000 houses damaged and the total estimated losses of from the flood as N2.6 trillion or $16.9 billion. The 2022 flood affected 34 out of 36 states in Nigeria, impacted over 2.8 million peoples, with over 1.3 million people displaced, over 600 lives lost and over 200 000 houses partially or totally damaged [16-17].

Flooding is the most wide-reaching disaster in Nigeria, and is a threat to Nigeria's quest to achieve the sustainable development goals (SDGs) as there is increasing vulnerability of populations and infrastructure to flooding and flood related hazards. Reducing disaster risk is therefore central to achieving sustainable development especially in developing countries [12,18-19].

FLOOD RISK MANAGEMENT IN NIGERIA

Preventing and managing disaster situations (such as flooding) effectively and ensuring sustainable regional development have been a source of major concern of academics, engineers, planners, decision-makers and different levels of government. Meanwhile, because the meantime interval between floods can be irregular and not easy to predict stakeholders tend to forget the lessons of the 'last' flood disaster and become relaxed until another flood strikes [12,6].

Even though Nigeria is signatory to various agreements and protocols such as the SDGs and Sendai Framework, most of the flood risk management efforts in Nigeria have been reactionary and short-term post-hazard measures such as relief materials distributions, erection of internal displaced peoples' camps. Disaster management is still at infancy stage in Nigeria. The lack of relevant legal and policy frameworks by all levels of government in Nigeria is an indication of the low importance given to controlling and managing flooding in Nigeria [20,12,10].

While there have been various interventions in the past, there is a lack of integrated and sustainable Flood Risk Management (FRM) systems and practices in Nigeria. Responses to the past flooding events have been piecemeal, mainly focusing on alleviating immediate and short-term needs such as rebuilding of destroyed assets. While enormous resources and investment have been put into a number of structural FRM measures, there has been a limited adaptation of these technologies to the Nigerian socio-technical environment as well the absence of the required knowledge transfers to Nigerian experts [6].

The absence of a national FRM strategy or comprehensive flood risk maps, for example, are indicators of the lack of adequate attention paid to Nigeria's flooding problem. Also, the lack of inter-agency coordination, substandard and weak infrastructures, inadequate drainage network, high urban poverty, low level literacy, absence of holistic or system thinking in urban system planning and development, the disconnection between FRM systems and other subsystems of the built environment, cultural barriers and weak institutions characterize current FRM practices. Designing and implementing adequate FRM strategies comprising proper spatial planning and infrastructure would help in controlling the floods. This is possible through coordinated and committed participation of all stakeholders in the industry using the appropriate regulations as the key guide and document for quality management [6,10,21].

In most Nigerian urban centres, it can be observed that there is a disconnec¬tion between FRM systems and other elements of the urbanization process; there is need to strengthen risk reduction and mitigation capacity. Some of the challenges in reducing and mitigating flood risk are related to inadequate flood control infrastructure, aging or weak dams, inadequate dam monitoring and maintenance, lack of flood risk awareness, along with inadequate solid waste, sewage, drainage, and flood zone management. Urban areas require special consideration, with integrated flood risk management, planning, and enforcement. Many cities or small towns are vulnerable to flood risk, and priority should be given to preparing and implementing structural and nonstructural flood control strategies [6,1].

In tackling flood risk in Nigeria, the main focus has been on structural measures coupled with over dependence on imported expertise and technologies. Nigeria can strengthen flood risk management and protect human lives, as well as properties and infrastructure, by adopting cost-effective strategies that focus on managing floods and integrating the concept of living with floods, protecting key assets, and minimizing losses. Nigeria has poor flood warning systems as well as a poor flood insurance scheme. Flood Risk Management measures are aimed at reducing the likelihood and impact of floods. It encompasses the prediction of flood hazards, socio-economic factors and consequences, and measures/tools for risk reduction. Hence, building resilience capability to cope with increasing climate variability remains the most viable option for FRM in Nigeria [6,10,1].

Throughout the world, countries have recognized the need to formulate a clear regulatory agenda aimed at the prevention, management and reduction of disasters. A number of steps taking in the right direction would boost the capacity to confront most natural disasters such as flooding. An integrated and holistic approach to development whereby flood management is a high priority sub-system has been identified as the only sustainable approach to FRM. This approach to development will require a high level of coordination and integration among the various agencies of the Nigerian government. Inter-agency coordination and integration, vis-a-vis FRM, will allow for the interrelations exiting among urbanization processes and systems to be systematically explored and exploited in a complimentary manner. A good proactive approach such as the resilience system would strengthen flood mitigation in Nigeria. The central aim of this approach is to identify ways in which exposed communities can better anticipate, mitigate, prepare for and cope with the occurrence of present and future hazard events. The resilience approach would enable the system to absorb hazard disturbances, learn from mistakes in past responses, reorganize after disturbance events, and prepare for possible future shocks and anticipated impacts. Thus, resilience encourages managing hazards instead of merely controlling them [12,6,22].

Goal 9 (build resilient infrastructure to promote sustainable industrialization and foster innovation) and Goal 11 (making cities and human settlements inclusive, safe, resilient and sustainable) of the Sustainable Development Goals (SDGs) as established by the United Nations (UN) in 2015 both address infrastructure resilience. The need therefore arises for long-term and sustainable FRM measures to be employed in reducing the effect of this menace to its barest minimum, one of which is the implementation of infrastructure resilience.

INFRASTRUCTURE RESILIENCE

Resilient construction has been in place for centuries, but only relatively recently has it been used as a systematic component of an integrated flood risk management strategy. Resilient buildings are designed and constructed in such a way to avoid, prevent, or reduce the damage caused when flooding takes place. They can play an important part in flood risk management strategy by reducing damage and, importantly, speeding up the recovery process [23]. Holling [24] first introduced the concept of resilience as the ability of an ecological system to absorb and recover from external shocks. However, the widely accepted UN definition for resilience is: “The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions” [25].

The context of the resilience of development interventions and the resilience of infrastructure could be considered as both in terms of the resilience of infrastructure itself, and how infrastructure affects resilience: both of other infrastructure systems, and of individuals, households and communities [26].

Resilient infrastructure is about people. It is about the households and communities for whom infrastructure is a lifeline to better health, better education, and a better livelihood. It affects people's well-being, their economic prospects, and their quality of life. Resilience is of importance to both developed and developing countries, as disaster and climate impacts are not a function of a country's Gross Domestic Product (GDP), and risks apply to both existing and new infrastructures. In developing countries, infrastructure disruptions are an everyday concern. When infrastructure fails, it undermines businesses, job creation, and economic development. With rapidly growing populations and a changing climate increasing the frequency and intensity of natural hazards, the need to adapt and invest in resilience should be an urgent priority. A resilient infrastructure system will be sufficiently robust, have sufficient redundancy, and allow for sufficient resourcefulness to resolve issues with sufficient rapidity to continue operating at normal or near normal performance levels. Infrastructure investments made today are vital as they will not only need to respond to future climate impacts on the infrastructure itself, but will determine how future users live. Climate resilient infrastructure must enable communities and society to both mitigate and adapt to climate change impacts [27,26]. The overlapping and complementary interaction between resilient assets; resilient infrastructure and resilient users (see fig. 1).

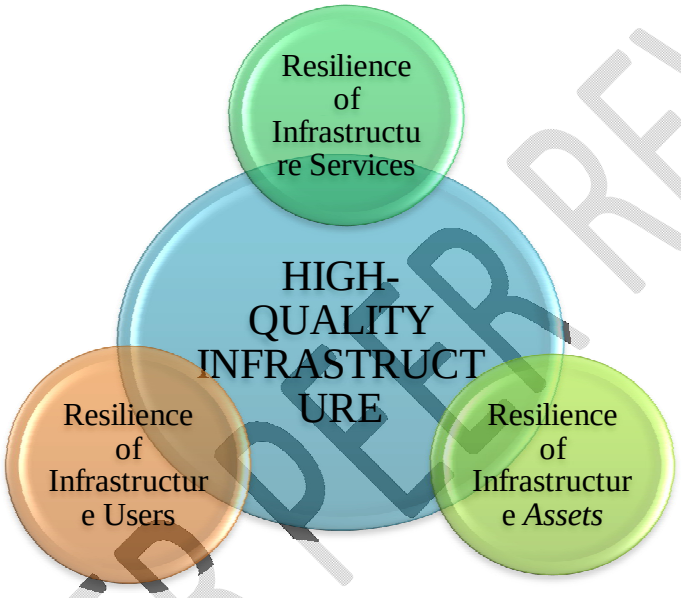

Fig. 1: Interaction between resilient assets; resilient infrastructure and resilient users (Source: Hallegatte *et al.,* [27])

Hallegatte *et al.,* [27] highlighted the following as regards resilient infrastructure

i. the lack of resilient infrastructure is harming people and firms

ii. investing in more resilient infrastructure is robust, profitable, and urgent

iii. good infrastructure management is the necessary basis for resilient infrastructure

iv. institutional mandates and strategies should be defined for infrastructure resilience

v. resilience in the regulations and incentive systems of infrastructure sectors, users, and supply chains should be introduced

vi. decision making should be improved through data, tools, and skills

vii. appropriate financing be provided – especially for risk-informed master plans, asset design, and preparedness

Nofal and van de Lindt [28] observed that predicting flood losses is the first step to study the resilience of a certain community. Quantifying flood losses for each of the different community sectors will help define the scope of the recovery process. Flood loss is often classified into direct and indirect flood losses. Direct flood loss is the physical damage induced by the event due to objects and their contact with water such as buildings and contents within the inundated area. Indirect loss is derived from the disruptions to businesses, public services, and can lead to business interruption inside and outside the inundated area. The flood losses are further classified into tangible and intangible losses, depending on whether or not these losses can reasonably be evaluated in monetary terms or not. Tangible losses can be monetized but intangible losses are the damages that cannot be directly assessed in monetary terms. A summary of the different classification of flood losses with examples for each one, are presented in Table 1, while the classification of the actions that communities may choose to adopt to mitigate flood impacts and speed the recovery process are presented Table 2.

Table 1: Classifications for Flood Damages (Source: Nofal and van de Lindt, [28])

LOSS TYPE	DIRECT	INDIRECT
Tangible	Physical impacts of flooding on community assets in a flooded area. • Damage and disruption to the physical infrastructure (buildings, bridges, water supply systems, water treatment plants, wastewater treatment plants, railroads, electric power networks, transportation network buildings and their contents). • Business disruption or closure in the flooded area. • Damage to crops in agriculture areas and loss of soil due to the water saturation.	Socio economic impacts of flooding on public services outside the flooded area. • Business disruption or closure outside the flooded area. • Public services disruption or closure outside the flooded area (transportation network, water supply network, bridges, railroads, facilities, and public utilities). • Closure of companies outside the flooded areas. • The inflation rate increase due to economic losses, business disruption and business closure.
Intangible	Physical impact on humans, ecosystem and culture. • Human life losses, injuries and psychological stresses. • Loss of ecological system. • Loss of cultural heritage (such as museums, old cities and libraries).	Societal impacts of flooding outside the flooded community • Long term health effects. • Resident out migration • Losing trust in government and/or authorities.

The resilience approach however, requires standard procedures to be formulated to guide its use and implementation. Out of 36 states and the Federal Capital Territory in Nigeria, Lagos State is the only one that has enacted and published the relevant framework for infrastructure resilience. The document Lagos Resilience Strategy [29] was published by the Lagos State Government through the Lagos State Resilience Office (LASRO) in 2020. It is therefore imperative that the government at all levels in Nigeria (federal, state and local) follow that path towed by the Lagos State Government.

Table 2: Classification of the actions that communities may choose to adopt to mitigate flood impacts and speed the recovery process (Source: Nofal and van de Lindt, [28]).

RESILIENT MEASURE	SHORT-TERM	LONG-TERM
Pre-Disaster	Immediate precautionary measures for community to be implemented after flood warnings: • Construct temporary berms/levees. • Install pumps at critical locations. • Use Sandbags around emergency and critical facilities. • Encourage volunteers to help with filling and moving the sandbags. • Elevate interior building expensive components such as furniture, appliances, and important documents on higher shelves.	Community plans for 100-year flood or any recurrence intervals to protect the buildings located in the floodplain: • Construct permanent berms/levees. • Construct dams, flood exits, flood barriers, floodwalls, and flood gates. • Increase first-floor elevation for the buildings on the floodplain. • Elevate heaters and air conditions. • Reroute ductwork from the crawlspace to the attic.
Post-Disaster	Immediate actions for community to be implemented just after the flooding event: • Evacuation Plans. • Temporary shelters. • Secure the food chain. • Provide funds for the impacted buildings. • Encourage voluntary institutions to help with community recovery. • Start Recovery.	New community plans after the lessons learned from past flooding events: • Redesign the flood drainage network based on the lessons learned. • Offer buyout program for the buildings on the floodplain. • Adopt resilient construction methods for new buildings. • Retrofit of the impacted infrastructure to resist future flooding according to the new plans.

RECOMMENDATIONS

The following recommendations for practice as suggested below by Oladokun & Proverbs [6] and Hallegatte *et al.,* [27] should be considered and possibly implemented by the Nigerian government.

i. Adoption of an integrated resilient approach to Nigeria's urban infrastructural development and FRM.
ii. A review of ongoing and planned infrastructural projects with a view to optimizing their FRM capabilities while still meeting their intended purposes.
iii. Infrastructure resilience should be built into town planning and development activities; new property developments should strictly be resilient.
iv. Establishment of centre of excellence in Flood Risk Research and Capacity Development to serve as a multidisciplinary platform for generating effective strategic policies and efficient operational mechanisms for FRM in Nigeria.
v. Collaboration between relevant government agencies and professional bodies should be encouraged and strengthened.
vi. Adoption of pragmatic steps toward developing and including suitable FRM concepts and practices into the nation's educational curricula.
vii. Mobilizing and empowering more entrepreneurs into FRM solutions development and service delivery in Nigeria.

Table 3: Recommendations to address the obstacles to resilient infrastructure (Source: Hallegatte *et al.,* [27])

Recommendation	Actions
Get the basics right	• Introduce and enforce regulations, construction codes, and procurement • rules • Create systems for appropriate infrastructure operation, maintenance, and post-incident response • Provide appropriate funding and financing for infrastructure planning, construction, and maintenance
Build institutions for resilience	• Implement a whole-of-government approach to resilient infrastructure, building on existing regulatory systems • Identify critical infrastructure and define acceptable and intolerable risk levels • Ensure equitable access to resilient infrastructure
Create regulations and incentives for resilience	• Consider resilience objectives in master plans, standards, and regulations and adjust them regularly to account for climate change • Create economic incentives for service providers to offer resilient infrastructure assets and services • Ensure that infrastructure regulations are consistent with risk-informed land use plans and guide development toward safer areas
Improve decision making	• Invest in freely accessible natural hazard and climate change data • Make robust decisions and minimize the potential for regret and • catastrophic failures • Build the skills needed to use data and models and mobilize the know-how of the private sector
Provide financing	• Provide adequate funding to include risk assessments in master plans and early project design • Develop a government-wide financial protection strategy and contingency plans • Promote transparency to better inform investors and decision makers

CONCLUSION

With the annual cycles of flooding in Nigeria and its devastating consequences, FRM measures such as the resilient infrastructure approach will go a long way in strengthening and reduce the losses associated with flooding to the barest minimum.

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