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The Impact of Perennial Pluvial Flooding on the Architectural Quality and Performance of Residential Buildings in Selected Areas of Port Harcourt Metropolis

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Abstract
The study examined impact of perennial pluvial flooding on the architectural quality and performance of residential buildings in selected Areas of Port Harcourt Metropolis. Resilience Theory guided the theoretical framework of this study. The methodology integrates both primary and secondary data sources. With a population of 1,416, a sample frame of 708, and a sample size of 512 determined using the Taro Yamane method, the study employed field observations, surveys, and statistical analysis, including descriptive statistics. Additionally, Geographic Information Systems (GIS) were used to identify flood-prone areas within the metropolis. The findings also revealed that flooding negatively impacts building safety, aesthetics, comfort, and durability, with 80% of respondents reporting moderate damage and 25% highlighting severe effects on structural integrity. The study recommends the implementation of Blue-Green Infrastructure (BGI) in residential buildings. BGI combines natural systems with urban planning to reduce storm water runoff, improve water quality, and enhance urban livability. This guide provides practical guidance on implementing BGI in residential buildings, with the aim of promoting flood resilience and creating more sustainable and resilient communities. It applies to new and existing residential buildings in Port Harcourt Metropolis and proposed a flood-resilient design framework that incorporates architectural innovations, effective stakeholder involvement, and strong policy measures.

Keywords: Perennial Pluvial Flooding, Architectural Quality, Performance, Residential Buildings, Port Harcourt Metropolis

INTRODUCTION

Flooding occurs as a result of heavy or prolonged rainfall exceeding the absorptive capacity of the soil and the flow capacity of rivers, streams, and coastal areas. A flood is an overflow of water that submerges land that is usually dry (NGS, 2014). Dogondaji et al. (2017) observed that flooding is the occurrence of an excessive volume of water in an area usually dry, which has refused to percolate or flow away easily. It usually occurs mostly when there is heavy downpour in an area of land, and all the rain does not sink into the soil but flows on the earth’s surface as floods (Agbonkhese et al., 2017). Flooding is a type of extreme weather event that happens when there is heavy rainfall in a short time. Based on the types of flooding, three major types are identified: river flooding, coastal flooding, and urban flooding. Thus, river flood plains and coastal areas are most susceptible to flooding arising from natural factors such as heavy downpour. However, flooding can also occur in areas with usually long periods of heavy rainfall that are not located along rivers or coastal areas. River flooding is defined as when the water normally flowing in the river channel overflows its banks and spreads out onto the surrounding land area or its flood plain (Nelson, 2015; Dimkpa, Ohochuku, Adibe, & Okey-Ejiowhor, 2024). River flooding poses a major problem to people living in residential areas along the rivers. For example, the Mississippi River has overflowed its banks for thousands of years, causing extensive damage to properties in cities such as New Orleans during 2005's Hurricane Katrina. River flooding is projected to increase in many regions of the world, particularly Africa and Asia, owing to climate change and socio-economic changes and development (Merz et al., 2021). The impacts of flooding are expected to rise at a global level due to population increases, economic growth, and climate change; hence, understanding the physical and spatiotemporal characteristics of risk drivers (hazard, exposure, and vulnerability) is required to develop effective flood mitigation measures (Tang et al., 2021).

One of the most prevalent natural disasters in Nigeria is perennial flooding. Many states are increasingly experiencing annual flooding during the rainy season, and a growing body of evidence links these events to climate change. Climate change refers to the periodic modification of Earth's climate brought about by atmospheric changes and interactions with various geologic, chemical, biological, and geographic factors within the Earth system (Intergovernmental Panel on Climate Change [IPCC], 2021; Jackson, 2021). Coastal floods, resulting from extreme tidal conditions and storm surges, are the leading causes of flooding in low-lying coastal areas (Andrew, Samuel, & Caitlyn, 2020). Fluvial or river floods occur when excessive rainfall or snowmelt causes rivers to overflow, with severity depending on factors such as precipitation, soil saturation, and terrain (Andrew, Samuel & Caitlyn, 2020; Okey- Ejiowhor, Amakiri, & Nkeiruka, 2022). Pluvial floods occur when intense rainfall overwhelms urban drainage systems or flows over impervious surfaces, causing water accumulation in urban areas, even those above coastal and river floodplains (Terence, Ayodele & Samuel, 2020). When floods occur, substantial infrastructural damage is caused, for example, bridges are washed away, roads marooned, and floodwater gets contaminated with raw sewage. Additionally, structural failures occur when dynamic and hydrostatic loads and debris impacts affect buildings. Moreover, foundations can be undermined by erosion and scouring. Properties are also displaced by buoyancy forces. Flooding also disrupts services and causes loss of infrastructure and lives

In Nigeria, floods have become an annual occurrence, particularly in states of the federation located along major rivers Niger and Benue, such as Adamawa, Anambra, Bayelsa, Benue, Delta, Edo, Kebbi, Kwara, Nasarawa, and Taraba. River flood plains, stream banks, and coastal areas are the most susceptible to flooding. Flooding is the most common disaster in Nigeria, with the majority of Nigeria's states increasingly suffering from annual flooding during the seasons, caused by increased precipitation linked to climate change. In 2012, the country witnessed its worst flood in 50 years, where 363 people died by the end of October of that year. Some 2 million people were displaced, and 618,000 houses were destroyed. In 2022, as of October 2022, the Nigerian Federal Government stated that 2.5 million people were affected, with 82,000 houses damaged by the floods of 2022 (Aminu et al., 2022). In fact, the yearly occurrence of floods in Nigeria is often a result of inadequate infrastructure and nonimplementation of environmental guidelines on flood prevention and mitigation (Idrees et al., 2022; Amakiri, Nkeiruka, & Okey-Ejiowhor, 2022). The Nigerian Hydrological Services Agency (NIHASA) usually issues an annual flood outlook that predicts flood risks in states and local government areas (LGAs), but not much is done by those in authority to prevent and control the floods. This study focused on the effect of flooding on the Architectural Quality and Performance of Residential Buildings in Selected Areas of Port Harcourt Metropolis.

LITERATURE REVIEW

Concepts of Flooding

Flooding can comprise overflow of a river as a result of prolonged seasonal rainfall, rainstorms, snowmelt, dam-breaks, accumulation of rainwater in low-lying areas with a high water table, or inadequate storm drainage. Floods could also be caused by the intrusion of seawater onto coastlands during cyclonic/tidal surges (Handmer, Penning-Rowsell, and Tapsell, 1999; Stoltman, Lidstone, and DeChano, 2004). Floods have been noted to cause about one-third of all deaths, one-third of all injuries, and one-third of all damage from natural disasters (Askew, 1999).

Flooding in various parts of Nigeria has forced thousands of people away from their homes, destroyed businesses, polluted water resources, and increased the risk of diseases (Jeb and Aggarwal, 2008; Etuonovbe, 2011; Olorunfemi, 2011). The occurrence of floods in Nigeria is not a recent phenomenon (Ayoade, 1979; Ayoade and Akintola, 1980; Olaniran, 1983; Ologunorisa and Terso, 2006; Adeloye and Rustum, 2011). The recent occurrences of flooding in Nigeria such as the Sokoto flood in 2010, the Ibadan flood in 2011, the Lagos flood in 2011, most parts of the country in 2012, and the recent flooding of 27 states in 2022, have shown that flooding is one of the major environmental problems faced in Nigeria. Widespread flooding killed more than 500 people in Nigeria in 2022, left around 90,000 homes underwater, and blocked food and fuel supplies. The floods have hit 27 of Nigeria's 36 states and impacted around 1.4 million people (NEMA). Nigerian authorities said flooding caused by heavier-than-usual rains had been building and intensified after water releases from the Lagdo dam in neighbouring Cameroon. To plan for floods, one has to understand the type or types of floods that might be encountered. Each one has a different impact in terms of its duration, how it occurs, how it is forecast, the damage it causes, and the type of protection needed.

Causes and Impacts of Perennial Pluvial Floods in Port Harcourt Metropolis

Several studies have identified the causes of perennial pluvial flooding in Port Harcourt Metropolis and have attributed it to one or all of the following; topography, soil/vegetation/river alteration, increased heavy rainfall, uncontrolled waste dumping, land use change, and unplanned urbanization (Oriola, 1994; Onokerhoraye, 1995; Parker, 1999; Folorunsho and Awosika 2001; Ologunorisa, 2004; Ogba and Utang, 2008; Adeloye and Rustum, 2011). Perennial pluvial flooding in Port Harcourt Metropolis can be attributed to a combination of these factors. Based on available literature and data, the causes of perennial pluvial flooding in Port Harcourt Metropolis include:

Heavy Rainfall and Climate Change: Because of climate change, rainfall variation is projected to continue to increase. Precipitation in southern areas is expected to rise and rising sea levels are expected to exacerbate flooding and submersion of coastal lands (Beyioku, 2016). Port Harcourt Metropolis experiences high levels of rainfall throughout the year, with particularly intense rainfall during the wet season. Heavy and prolonged rainfall events overwhelm the drainage systems, leading to water accumulation and subsequent flooding. Climate change exacerbates the situation, with changing rainfall patterns and an increased frequency of extreme weather events contributing to more intense and frequent floods.

Inadequate Drainage Infrastructure: The city's drainage infrastructure has not kept pace with rapid urbanization and population growth. The existing drainage systems often lack sufficient capacity and are unable to efficiently manage the volume of water during heavy rainfall. Additionally, inadequate maintenance and the dumping of solid waste into drains contribute to blockages and hinder the flow of water (Chiadikobi et al., 2011).

Encroachment on Waterways and Floodplains: Uncontrolled urban expansion and improper land use practices, such as construction on floodplains and encroachment on natural waterways, disrupt the natural flow paths of water (Oriola, 1994). This reduces the storage capacity for excess water and increases the risk of flooding. The loss of natural buffers, such as wetlands and floodplains, further exacerbates the impacts of flooding.

Deforestation and Soil Erosion: Unregulated deforestation, particularly in upstream areas, leads to increased surface runoff and soil erosion (Adeloye & Rustum, 2011). The removal of vegetation reduces the ability of the land to absorb water, resulting in enhanced runoff and sediment transport. Deforestation also contributes to the clogging of drains and water channels with sediment, further impeding drainage systems (Ogba & Utang, 2008).

Inefficient Waste Management: Improper waste disposal practices, including the dumping of solid waste into drains and water bodies, obstruct the flow of water and exacerbate drainage issues (Folorunsho & Awosika, 2001). Blocked drains and water channels reduce the capacity of the drainage systems, leading to increased flood risks.

Lack of Urban Planning and Regulation: Inadequate urban planning and zoning regulations have contributed to haphazard development, particularly in flood-prone areas, the absence of strict regulations on land use and construction standards has allowed for the encroachment on floodplains and the development of infrastructure that is not resilient to flooding (Oriola, 1994).

Floods: Some Major Flood Events in Nigeria

By studying the past, we learn about the present and are able to plan for the future (Angelakis et al., n.d.). Since 2012, Nigeria has experienced numerous significant flood events that have caused substantial damage, loss of life, and disruption to communities and economies. These events highlight the critical need for improved flood management, infrastructure, and preparedness strategies. The major flood events featured the different types of floods. But for this study, the focus was on the part of pluvial floods. This detailed review, therefore, delved into the major flood events of 2017 and 2021, examining their causes, impacts, and the lessons learned to better prepare for future occurrences.

The 2017 Floods

The 2017 floods in Nigeria were a devastating natural disaster that impacted several regions of the country, resulting in about 18 deaths, displacement of communities, and widespread damage to property and infrastructure. These floods were primarily triggered by intense and prolonged rainfall, which overwhelmed rivers, reservoirs, and drainage systems, leading to severe inundation across many states.

Causes of the 2017 Floods

The primary cause of the 2017 Nigerian floods was heavy and sustained rainfall during the rainy season. Nigeria's geographical location and climatic conditions make it prone to seasonal flooding, especially during the peak months of the rainy season from June to September. In 2017, the intensity of the rains was unusually high, exacerbated by climate change factors, which contributed to the extreme weather patterns observed. Another contributing factor was poor urban planning and inadequate drainage infrastructure in many cities and towns. Rapid urbanization without corresponding improvements in infrastructure led to clogged drainage systems, which could not handle the volume of water. This situation was further aggravated by deforestation and land degradation, which reduced the land's natural ability to absorb and manage rainfall (Sullivan, 2022).

Impact on Affected Regions

The floods of 2017 affected numerous states across Nigeria, with particularly severe impacts in Benue, Kogi, Niger, and Lagos States.

Benue State: One of the worst-hit areas, Benue State, experienced severe flooding that displaced over 100,000 people. The flooding was so severe that it submerged entire communities, destroying homes, farmlands, and critical infrastructure. The state capital, Makurdi, saw significant portions underwater, leading to the displacement of thousands of residents who sought refuge in temporary camps and shelters (Olujobi, 2024).

Kogi State: Kogi State, located along the confluence of the Niger and Benue rivers, also experienced catastrophic flooding. The rise in water levels of both rivers led to widespread inundation, displacing thousands and causing extensive damage to property and agricultural lands. The flooding disrupted transportation and communication networks, hampering relief efforts.

Niger State: In Niger State, the floods resulted in the displacement of many communities, particularly those situated along riverbanks. The swollen rivers led to the destruction of homes and farmlands, severely impacting the livelihoods of residents who rely on agriculture.

Lagos State: As Nigeria's economic hub, Lagos was not spared from the flooding. Urban areas in Lagos experienced significant waterlogging, leading to traffic congestion, property damage, and disruptions to business activities. The city's drainage systems were overwhelmed, highlighting the urgent need for infrastructural improvements to mitigate future flood risks.

Rivers State: Residents of Port Harcourt, the capital city of Rivers State, reported that they were counting their losses after three days of continuous rainfall which started in the early hours of 22nd July 2024. The 2017 floods caused widespread flooding and destruction of property. According to reports, three people lost their lives in various parts of the city due to the flooding. Areas such as D-Line, Diobu, Elekahia, and Ada-George were identified as being the hardest hit. Besides the loss of property, many victims were temporarily displaced from their homes. (TVC News, 2017).

Humanitarian Response and Relief Efforts

The scale of the disaster prompted a swift response from both the Nigerian government and international organizations. The Federal Government, through the National Emergency Management Agency (NEMA), coordinated relief efforts, providing emergency assistance to affected populations. This included the distribution of food, clean water, medical supplies, and temporary shelters to those displaced by the floods.

International humanitarian organizations and local NGOs also played a critical role in the response. They assisted in conducting needs assessments, delivering aid, and supporting the establishment of temporary camps for displaced persons. These efforts were crucial in alleviating the immediate suffering of those affected and preventing further health crises due to waterborne diseases and poor sanitary conditions.

Long-Term Implications and Lessons Learned

The 2017 floods underscored the urgent need for comprehensive flood management and mitigation strategies in Nigeria. The disaster highlighted the vulnerabilities of urban and rural communities to extreme weather events and the consequences of inadequate infrastructure and poor environmental management.

In response to the floods, there were calls for improved urban planning, investment in resilient infrastructure, and the implementation of early warning systems to better prepare for and respond to future flood events. Enhancing community awareness and preparedness through education and training programs was also recognized as a critical component in reducing the impact of such disasters.

The floods also emphasized the importance of addressing broader environmental issues, such as deforestation and land degradation, which contribute to increased flood risks. Reforestation and sustainable land management practices were identified as necessary measures to enhance the natural resilience of the environment to heavy rainfall and flooding.

Plate 1 Flooding of Federal Road Safety Commission Port Harcourt Office along Aba Road. Source: Echendu, (2021)

Benefits of Nature-Based Mitigation and Adaptation Strategies

Nature-based mitigation and adaptation strategies for flooding offer numerous benefits, including:

I. Reduced flood risk: By restoring and preserving natural ecosystems, these strategies can help to reduce the likelihood and severity of flooding (World Bank, 2019).
II. Improved water quality: Natural ecosystems can help to filter and purify floodwaters, improving water quality and reducing the risk of waterborne diseases (Mitsch & Gosselink, 2015).
III. Enhanced biodiversity: Nature-based strategies can help to preserve and restore natural habitats, promoting biodiversity and ecosystem services (IUCN, 2019).
IV. Increased community resilience: By promoting sustainable land use practices and enhancing community awareness and preparedness, nature-based strategies can help to increase community resilience to flooding (UNDRR, 2019).

V. Cost-effective: Nature-based strategies can be more cost-effective than traditional engineering approaches, which often require significant investment in infrastructure (European Commission, 2019).

Challenges and Limitations

While nature-based mitigation and adaptation strategies for flooding offer numerous benefits, there are also challenges and limitations to consider, including:

I. Land availability: Restoring and preserving natural ecosystems often requires significant land areas, which can be a challenge in densely populated urban areas (Fletcher et al., 2015).
II. Community engagement: Nature-based strategies often require community engagement and participation, which can be time-consuming and challenging to achieve (IUCN, 2019).
III. Funding: Implementing nature-based strategies can require significant funding, which can be a challenge for communities with limited resources (World Bank, 2019).
IV. Policy and regulatory frameworks: Nature-based strategies often require supportive policy and regulatory frameworks, which can be lacking in some countries (European Commission, 2019).

Nature-based mitigation and adaptation strategies for flooding offer a valuable approach to reducing flood risk and promoting community resilience. By restoring and preserving natural ecosystems, these strategies can help to reduce the likelihood and severity of flooding, improve water quality, and enhance biodiversity. While there are challenges and limitations to consider, the benefits of nature-based strategies make them an important tool in the fight against flooding.

Floods: Sponge City Concept

The Sponge City Concept is a innovative approach to urban flood management that has gained significant attention in recent years (Fletcher et al., 2015). The concept involves designing cities to absorb and filter rainwater, reducing the burden on drainage systems and minimizing the risk of flooding (Li et al., 2019). This report provides an overview of the Sponge City Concept, its benefits, and examples of its implementation in cities around the world. The Sponge City Concept is a holistic approach that integrates urban planning, architecture, and engineering to create sustainable and resilient cities (Wuhan Municipal Government, 2019). The concept has been recognized as a key strategy for mitigating the impacts of urbanization on flood risk (Fletcher et al., 2015).

Sponge City: Definition

A sponge city is an urban area designed to absorb and filter rainwater, reducing the burden on drainage systems and minimizing the risk of flooding (Fletcher et al., 2015). The concept is inspired by the natural water cycle, where rainwater is absorbed by the soil, filtered by vegetation, and slowly released into waterways (Mitsch & Gosselink, 2015). Sponge cities aim to replicate this process through the use of green infrastructure, such as parks, green roofs, and permeable pavements (Li et al., 2019). Green infrastructure is a key component of sponge cities, as it provides a range of ecosystem services, including stormwater management, air quality improvement, and habitat creation (Benedict & McMahon, 2006). The use of green infrastructure in sponge cities can also help to mitigate the urban heat island effect, improve air quality, and enhance biodiversity (Taha, 1997).

The concept of sponge cities is not new, but it has gained significant attention in recent years due to its potential to mitigate the impacts of urbanization on flood risk (Fletcher et al., 2015). The concept has been implemented in several cities around the world, including Chicago, Rotterdam, Singapore, Copenhagen, and Wuhan (City of Chicago, 2019; City of Rotterdam, 2019; Urban Redevelopment Authority of Singapore, 2019; City of Copenhagen, 2019; Wuhan Municipal Government, 2019). These cities have implemented a range of green infrastructure initiatives, including green roofs, rain gardens, permeable pavements, and urban parks, to reduce stormwater runoff and improve water quality.

Sponge City: Benefits

Sponge cities offer numerous benefits, including reduced flood risk, improved water quality, enhanced biodiversity, mitigated urban heat island effect, and improved public health (Li et al., 2019). The use of green infrastructure in sponge cities can also help to improve air quality, reduce noise pollution, and enhance aesthetic value (Benedict & McMahon, 2006). Additionally, sponge cities can provide opportunities for physical activity, social interaction, and community engagement, which can help to improve public health and well-being (Sallis et al., 2016).

Sponge City: Examples

As cities around the world face increasing challenges related to urbanization, climate change, and water management, the concept of the "sponge city" has gained significant attention (Li et al., 2019). A sponge city is an urban area that is designed to absorb and filter rainwater, reducing the risk of flooding and improving water quality. Here are five examples of cities that are implementing sponge city initiatives:

Chicago, USA: Chicago's Green Infrastructure Plan aims to reduce stormwater runoff and improve water quality through the use of green roofs, rain gardens, and permeable pavements (ProQuest, n.d.). The plan, which was launched in 2014, includes a range of initiatives, such as the creation of green infrastructure in public spaces, the implementation of green roofs on private buildings, and the use of permeable pavements in urban areas (City of Chicago, 2014). According to a study by the University of Illinois, Chicago's green infrastructure plan has the potential to reduce stormwater runoff by up to 70% (University of Illinois, 2018).

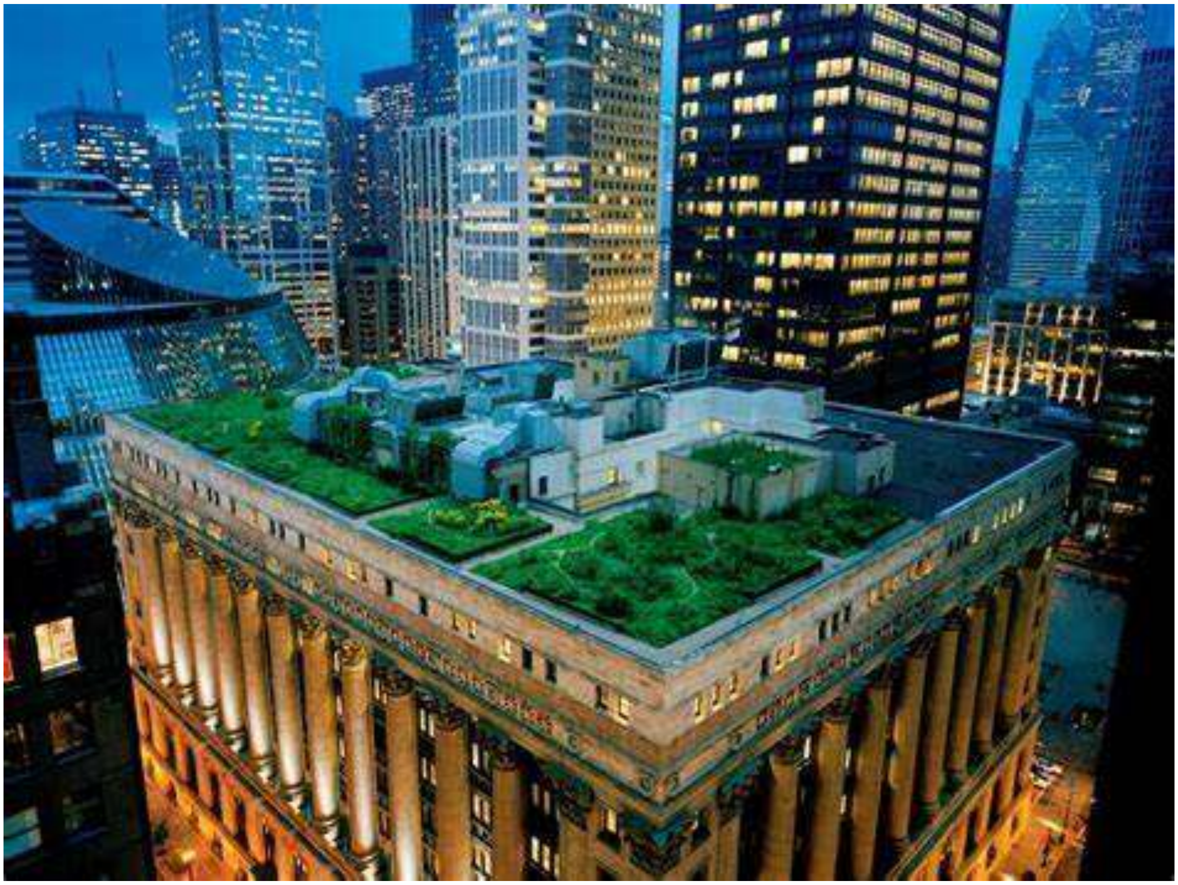

Plate 2. One Central Park, Chicago, Source: Cook, (2014)

Rotterdam, Netherlands: The Netherlands, literally translating to "low-lands," is famously situated below sea level. To cope with this unique challenge, the country has developed and implemented numerous innovative strategies to coexist with water, minimizing the risk of flooding over the years (Jonkman & Kelman, 2005). Rotterdam's Water Management Plan includes the creation of green roofs, urban parks, and flood-resistant construction to reduce the risk of flooding (City of Rotterdam, 2019). The plan, which was launched in 2013, aims to make Rotterdam a "water-resilient" city by 2025 (City of Rotterdam, 2013). According to a study by the Delft University of Technology, Rotterdam's water management plan has reduced the risk of flooding in the city by up to 50% (Delft University of Technology, 2019).

The Water Square Benthemplein in Rotterdam, Netherlands, is a pioneering example of urban design that combines public space and stormwater storage (Salinas et al., 2014). This innovative square holds a twofold strategy, serving as both a public space and a stormwater storage facility. By integrating these two functions, the square provides a unique solution to urban flooding and climate change resilience. As part of Rotterdam's strategy to increase climate resilience through adaptive measures, the Water Square Benthemplein showcases a new approach to urban design (City of Rotterdam, 2019). The square's design allows it to store excess rainwater during heavy rainfall events, reducing the burden on the city's drainage system and minimizing the risk of flooding. In addition to its functional benefits, the Water Square Benthemplein also demonstrates a new model for funding high-quality public spaces. The square was largely financed by water management departments and innovation subsidies, highlighting the potential for collaborative funding approaches to support urban design initiatives (Zevenbergen et al., 2018).

Plate 3: **Benthemplein Water Square, Rotterdam. Source**: Salinas et al, (2014)

Singapore: Singapore's Urban Redevelopment Authority has implemented a range of green infrastructure initiatives, including green roofs, rain gardens, and permeable pavements, to reduce stormwater runoff and improve water quality (Urban Redevelopment Authority of Singapore, 2019). The initiatives, which were launched in 2014, aim to make Singapore a "City in a Garden" by 2030 (Urban Redevelopment Authority of Singapore, 2014). According to a study by the National University of Singapore, Singapore's green infrastructure initiatives have reduced stormwater runoff by up to 30% (National University of Singapore, 2020).

The Singapore Green Plan 2030 is an ambitious initiative launched on February 10, 2021, with the goal of advancing Singapore's national agenda on sustainable development (Zheng, 2021). The plan is built around five key pillars: City in Nature, Sustainable Living, Energy Reset, Green Economy, and Resilient Future. Under the City in Nature pillar, the plan aims to add 1,000 hectares of green spaces by 2035 and double the annual tree planting rate (Zheng, 2021).

The Sustainable Living pillar focuses on reducing carbon emissions, keeping the environment clean, and saving resources. Some of the targets include reducing household water consumption to 130 liters per capita per day, expanding the rail network to 360km, and tripling cycling paths to 1,320km (Zheng, 2021). The Energy Reset pillar aims to increase the use of cleaner energy and improve energy efficiency. Targets include increasing solar energy deployment by five-fold, greening 80% of buildings, and reducing energy consumption in HDB towns by 15% (Zheng, 2021). The plan also emphasizes the importance of a Green Economy, seeking green growth opportunities to create new jobs and transform industries (Ministry of Sustainability and the Environment, 2021). Finally, the Resilient Future pillar focuses on building Singapore's climate resilience and enhancing food security. The Singapore Green Plan 2030 is a "living plan" that will evolve over time, taking into account technological developments and public feedback (Ministry of Sustainability and the Environment, 2021).

Plate 4: Singapore Green Plan 2030: 1,000ha more green spaces & tripling cycling paths to 1,320km, Source: Zheng, (2021)

Copenhagen, Denmark: Copenhagen's Cloudburst Management Plan includes the creation of green roofs, urban parks, and flood-resistant construction to reduce the risk of flooding (City of Copenhagen, 2019). The plan, which was launched in 2012, aims to make Copenhagen a "cloudburst-resilient" city by 2030 (City of Copenhagen, 2012). According to a study by the Technical University of Denmark, Copenhagen's cloudburst management plan has reduced the risk of flooding in the city by up to 40% (Technical University of Denmark, 2020).

Plate 5: **Copenhagen Cloudburst Management Plan, Source**: Tauhid, (2021)

Wuhan, China: Wuhan's Sponge City Initiative aims to reduce flood risk and improve water quality through the use of green infrastructure, including green roofs, rain gardens, and permeable pavements (Wuhan Municipal Government, 2019). The initiative, which was launched in 2016, aims to make Wuhan a "sponge city" by 2030 (Wuhan Municipal Government, 2016). According to a study by the Wuhan University, Wuhan's sponge city initiative has reduced flood risk by up to 20% (Wuhan University, 2020).

The Wuhan Xinyuexie Park plays a vital role in the east eco-corridor of the Optics Valley Center Area, connecting Jiufeng Forest Park with Baoxie Lake (Tauhid, 2018). As the primary recreational space in the new Optics Valley CBD area, the park must incorporate several key functions:

I. Provide recreational space for various user groups, promoting an active lifestyle.
II. Preserve and enhance the natural stormwater corridor by integrating the Sponge City concept (Tauhid, 2018).
III. Offer opportunities for public access and environmental education, consistent with restored habitat areas.
IV. Establish connections between existing and restored hills and water bodies.

By serving these purposes, the park can fulfill the city's needs beyond merely improving its image and value (Tauhid, 2018). Upon completion, the park will be well-integrated into the Optics Valley city context, serving communities and user groups while improving local conditions (OBERMEYER Engineering Consulting, n.d.).

Figure 6: Wuhan Sponge City Initiative, Source: OBERMEYER, (n.d.)

Resilience Theory

Resilience Theory, introduced by Holling (1973), explores the capacity of systems to absorb disturbances and reorganize while undergoing change to retain essential functions. This theory has evolved to include urban resilience, particularly in the context of climate change and natural hazards (Meerow & Newell, 2019). In urban flooding scenarios, resilience involves three critical dimensions: resistance, recovery, and transformation. Resistance focuses on minimizing flood impacts through proactive measures like flood-proof architectural designs. Recovery emphasizes quick restoration of functionality after flood events, while transformation involves long-term adaptability to changing climatic conditions. Holling's foundational work highlights the adaptive capacity of systems, a principle crucial for designing buildings and urban spaces that can withstand and recover from flooding. Meerow and Newell (2019) extend this by defining urban resilience as "the capacity of urban systems to survive, adapt, and thrive despite chronic stresses and acute shocks." In Port Harcourt, resilience-thinking can inform architectural strategies such as elevated foundations, modular designs, and adaptive building materials that resist water damage. Dong, Yang & Li, (2022) note that resilient urban planning integrates local knowledge, community participation, and innovative designs to create flood-resistant cities. For example, incorporating flexible drainage systems and multi-functional spaces can enhance a city's ability to manage flooding while maintaining its socio-economic vitality. Zhang, Wu & Wang, (2023) provide a case study of urban resilience in flood-prone regions, emphasizing the integration of nature-based solutions and community-driven approaches. These insights are particularly relevant to Port Harcourt, where engaging local communities in flood mitigation strategies can enhance their effectiveness and sustainability.

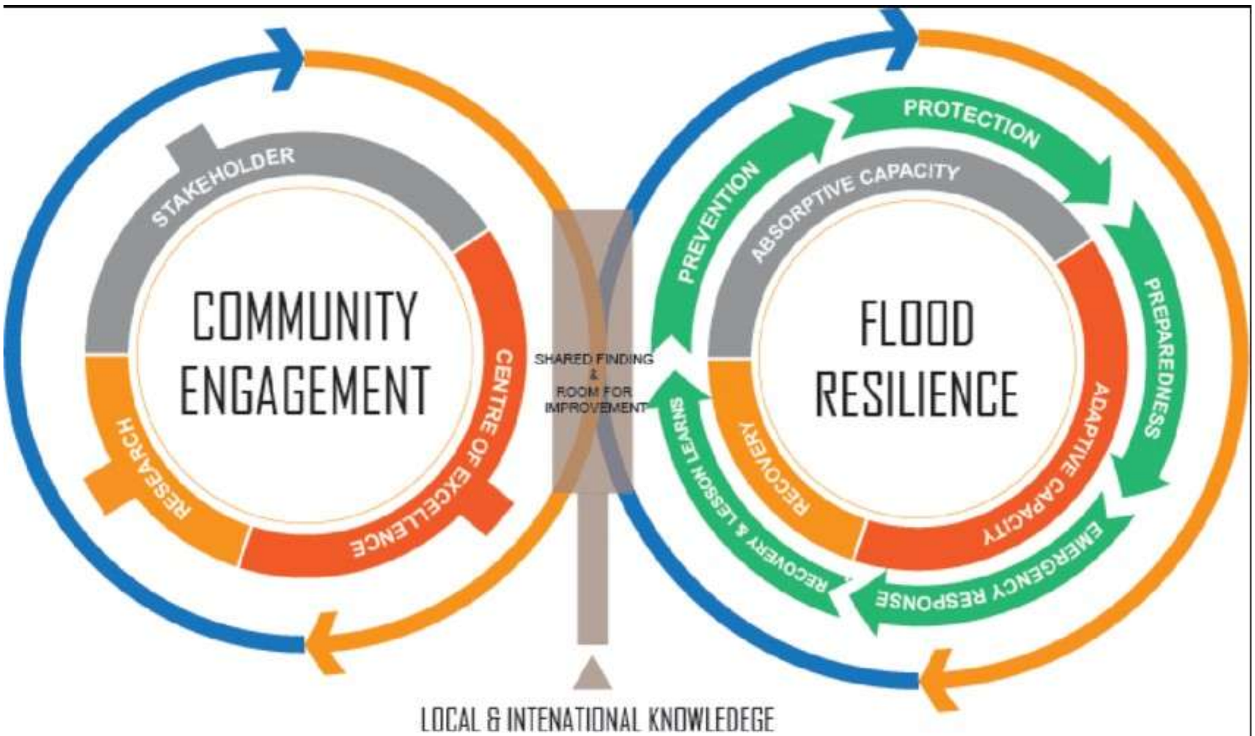

Figure 2.3 Relationships between Flood Resilience and Community Engagement.
(Source: Roslan, Jamaludin & Mohamad, 2015**).**

METHODOLOGY

Design

The quantitative component of the study provides objective data to complement the qualitative findings and offer statistical evidence on flood risks and mitigation strategies. Surveys were administered to residents, property owners, and local government officials in flood-prone areas of Port Harcourt Metropolis. The survey gathers data on the level of awareness among residents about pluvial flooding, current flood mitigation measures in place, and their views on various architectural strategies for flood prevention. The survey used a mix of Likert scale questions to measure attitudes and perceptions, along with close-ended questions. This approach allows for the quantification of public knowledge and opinions, as well as the identification of patterns in attitudes towards flood resilience. In addition, spatial analysis and mapping using Geographic Information System (GIS) tools was employed to map stratified flood-prone areas in Port Harcourt Metropolis, and analyze the relationship between urban development patterns, existing infrastructure, and the architectural features that influence flooding. Finally, the study incorporates flood impact data analysis. This was involved doing an urban flood vulnerability assessment of the selected areas in Port Harcourt Metropolis. It is essential for developing effective flood risk reduction and management strategies. Statistical tools will be used to analyze this data and explore the relationship between specific architectural features and the occurrence of flooding.

Population and Sampling

The targeted population for the study on Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis includes various stakeholders and groups directly or indirectly involved in addressing pluvial flooding challenges.

Residents of Flood-Prone Areas: Based on the work of Wizor & Mpigi, (2020) on the 25 most-flooded roads in Port Harcourt Metropolis. 13 regions (streets/roads) were chosen from the 25 most-flooded roads/streets in Port Harcourt Metropolis. 4 streets/roads were chosen from low-flooded areas, 5 from moderately-flooded areas, and 4 from high-flooded areas. A total of 13 streets/roads were considered for this research. However, Residents from these 13 selected flood-prone areas in Port Harcourt Metropolis form a key part of the population. These individuals provided valuable insights into local experiences with flooding, awareness of flood risks, and opinions on both existing and potential architectural strategies for flood mitigation. From each of the 13 areas, 20 compounds were selected, with one respondent per compound, resulting in a total of 260 respondents from this group.

Urban Planners and Architects: Professionals such as urban planners and architects are integral to the study, offering expert opinions on design and urban development strategies aimed at reducing flood risks. The research focuses on members of the Nigerian Institute of Town Planners (Rivers State branch), which has 570 members, and the Nigerian Institute of Architects (Rivers State branch), comprising 240 fully registered members. These professionals provide insights into the most effective architectural solutions for mitigating pluvial flooding.

Government Officials: Officials from relevant state ministries in Port Harcourt also form part of the population. These include the Rivers State Ministry of Urban Development and Physical Planning, with 84 staff members, River State Ministry of Housing with 134 staff, and the Rivers State Ministry of Environment, with 102 staff members. Their perspectives on flood management practices, policies, and regulations are crucial for understanding the institutional framework required to implement architectural adaptation strategies.

Community Leaders: Community leaders from the 13 selected flood-prone areas were included to represent the views of the broader community. These leaders play a critical role in advocating for local concerns and influencing decision-making processes related to flood mitigation, two leader or such as street chairman and a member were selected from each flood area, making a total of 26 stakeholders in this category.

Sample Frame

The sample frame for this study, "Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis", was thoughtfully developed to include a broad range of stakeholders with diverse roles and experiences related to flood mitigation. The approach ensures a balanced representation of opinions from individuals and institutions who are directly impacted or involved in addressing flooding challenges in the metropolis. The sample was selected by taking 50% of the total population from six key stakeholder groups.

Residents of flood-prone areas constitute a significant portion of the sample frame, with 130 participants selected from a population of 260. This group provides firsthand accounts of the flooding issues they face, offering valuable insights into the effectiveness of existing measures and highlighting the areas requiring improvement for better flood resilience.

The Nigerian Institute of Town Planners (Rivers State Branch) represents the largest group in the sample, with 285 participants selected out of 570. Town planners bring critical expertise to the study as they are responsible for urban development and zoning regulations. Their contributions help evaluate how planning practices can mitigate flooding in urban areas.

The Nigerian Institute of Architects also play a crucial role, contributing 120 participants from its total membership of 240. Architects are vital in designing buildings and infrastructure to withstand flooding. Their input focuses on assessing existing designs and recommending solutions tailored to the challenges posed by recurrent pluvial flooding in the region.

Officials from the Rivers State Ministry of Urban Development and Physical Planning are also included, with 42 selected from a population of 84. This group represents government involvement in urban planning and policy-making, ensuring that the study reflects institutional perspectives and strategies currently in place to manage urban flooding.

The Rivers State Ministry of Environment contributes 51 participants from a population of 102. Their expertise provides an understanding of the environmental dimensions of flooding, including its causes, impacts, and the role of sustainable practices in mitigating its effects.

The Rivers State Ministry of Housing contributes 67 participants from a total population of 134. Their specialized knowledge offers valuable insights into the environmental aspects of flooding, encompassing its underlying causes, consequences, and the importance of sustainable practices in addressing its challenges.

Finally, community leaders from flood-prone areas are represented by 13 individuals from a total of 26. These leaders provide collective insights on how floods affect local communities and the social and cultural dimensions of flood management. Their involvement ensures that community needs and priorities are well-represented in the findings.

In total, the sample frame includes 708 participants, drawn from a population of 1,416 across the seven stakeholder groups. By incorporating inputs from residents, professionals, government agencies, and community leaders, the study ensures a comprehensive understanding of the flooding problem. This diversity strengthens the analysis and helps develop practical, inclusive, and sustainable architectural strategies to address pluvial flooding in Port Harcourt Metropolis.

Sample size

The sample size for the research Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis was determined using the Taro Yamane formula. This statistical approach ensures the selection of a representative sample that accurately reflects the target population while minimizing sampling error. The study drew participants from seven key stakeholder groups, resulting in a total sample size of 512 individuals from an initial sample frame of 708. The Formula for Taro Yamane method is statistically given as follows:

$$n = \frac{N}{1+N\,(e)^2}$$

Where n = sample size

N = Population size

e = Level of significance or allowable error

1 = a constant

However, for each stakeholder, the estimated sample size was obtained for the sample frame of the population, for example, using the residents of flood prone area with a sample frame of 130 stakeholder for illustration, the Taro Yamane formula is thus substituted.

$$n = \frac{130}{1 + 130\,(0.05)^2}$$

$$= \frac{130}{1 + 130\,(0.0025)}$$

$$= \frac{130}{1.325} \quad = \quad 98$$

The Residents of Flood-Prone Areas constituted a significant portion of the sample size, with 98 participants selected from a sample frame of 130. The Nigerian Institute of Town Planners, Rivers State Branch had the largest sample frame of 285 members, from which 166 were selected. From the Nigerian Institute of Architects (Full Members), 92 individuals were selected from a sample frame of 120. The Rivers State Ministry of Urban Development and Physical Planning had a sample frame of 42 participants, with 41 selected for the study. The Rivers State Ministry of Environment had a sample size of 45 individuals, drawn from a sample frame of 51. While the

Rivers State Ministry of Housing has a sample size of 57 selected from a sample frame of 67. Finally, the Community Leaders of Flood-Prone Areas, representing grassroots stakeholders, had all 13 members included in the sample size. In summary, the total sample size of 512 participants encompassed a diverse range of stakeholders, ensuring the study benefited from a broad spectrum of expertise, experiences, and perspectives. This approach enhances the reliability of the findings and supports the development of effective architectural adaptation strategies to mitigate pluvial flooding in Port Harcourt Metropolis.

Instrumentation and Data Collection

This section outlines the instrumentation and data collection methods employed in this research, including the design and administration of surveys, interviews, and observational studies. The data collection instruments were carefully developed and validated to ensure that they captured the necessary information to address the research questions and objectives. This chapter provides an overview of the data collection process, including data collection techniques, and instrumentation used to gather both qualitative and quantitative data.

Instrumentation

This research utilized a variety of tools to collect comprehensive data on strategies for architectural adaptation to address recurring urban floods in Port Harcourt Metropolis. The instruments employed included well-structured questionnaires, interviews, and Geographic Information System (GIS) tools, each tailored to extract specific information from relevant stakeholders actively involved in flood management in the city. The structured questionnaire served as the main instrument for data collection, featuring both closed and open-ended questions. Its purpose was to gather diverse insights from key groups such as government officials, urban developers, architects, residents of affected neighborhoods, and community leaders in areas susceptible to flooding. The questionnaire was organized into sections.

Data Collection

This study employed a mixed-methods approach, integrating both qualitative and quantitative methods to gain an understanding of flood risks and mitigation strategies. Field Observations focused on flood-prone areas, examining drainage systems, building elevations, and construction materials, providing a baseline for adaptation strategies. Document Review was conducted using government reports, urban planning documents, and flood management policies to understand the historical and policy context of flood mitigation in Port Harcourt Metropolis. Additionally, Surveys were used to gather both expert and community perspectives. Semi-structured interviews were conducted with professionals, including architects, urban planners, and flood management experts, to gain expert insights into effective architectural strategies. Focus group discussions with community leaders were held to explore local views on current flood mitigation measures and potential solutions. Surveys were distributed to residents, property owners, and local government officials to assess their awareness of pluvial flooding and their opinions on architectural strategies for flood prevention. The surveys combined Likert-scale and close-ended questions, providing statistical data on public knowledge and attitudes.

Analytical Techniques for Data Collected/ / Analysis

The data obtained from the survey and GIS assessments were carefully organized and prepared for analysis. Responses from the structured questionnaire were initially sorted according to the demographic characteristics of respondents and the study's key research objectives. Descriptive statistical techniques, such as frequency distributions, percentages, and graphical representations, were utilized to interpret the responses. These methods facilitated the identification of participants' views on recurrent pluvial flooding in Port Harcourt Metropolis. In addition, spatial data analysis was conducted using ArcGIS. The GIS software was instrumental in visualizing and analyzing specific flood-prone areas within the study region. However, in mapping these vulnerable locations, ArcGIS provided valuable spatial context to the survey findings, enabling an understanding of the challenges and solutions related to pluvial flood mitigation in Port Harcourt Metropolis. The integration of descriptive statistics and GIS analysis ensured that the data was examined from multiple perspectives, contributing to well-rounded insights into strategies for addressing flooding issues in the study area.

Validity and Reliability of Research Instruments

To guarantee the accuracy and dependability of the tools used in this study, a thorough validation process was undertaken. The consistency of the structured questionnaire was evaluated using the test-retest technique. This approach involved administering the same set of questions to a small group of urban planners and other relevant stakeholders within Port Harcourt Metropolis at two different times. This allowed for an assessment of the uniformity in responses, ensuring the questionnaire effectively captured participants' views and experiences related to pluvial flooding and its mitigation. The variations observed between the two rounds of responses were reviewed, and modifications were made to improve the questionnaire's reliability. Additionally, the GIS tools utilized in this research, particularly ArcGIS, were rigorously tested by a certified GIS specialist before being deployed for data collection. This preliminary evaluation ensured the software's capability to accurately extract and analyze spatial data related to pluvial flooding within the study area. The GIS tools were also assessed to confirm their reliability in providing consistent results throughout the study. This step was critical in verifying that the spatial data collected was both precise and dependable. However, in employing the test-retest method for the questionnaire and subjecting the GIS tools to expert evaluation, the study ensured that all research instruments were both valid and robust. These efforts ensured the collection of high-quality, reliable data that was essential for developing effective architectural strategies to mitigate recurring pluvial flooding in Port Harcourt Metropolis. The combined validation process enhanced the credibility of the research findings and supported the study's objectives.

RESULTS AND DISCUSSION

The analysis of the questionnaire responses on the level of participation and data collection efficiency for the research on Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis. However, out of the total 512 questionnaires distributed, an impressive 95% (488) were completed and returned by the respondents. This high return rate demonstrates strong engagement and commitment from the participants, ensuring a robust dataset for the study.

Conversely, only 5% (24) of the questionnaires were not returned, indicating a minimal loss of data and underscoring the effectiveness of the distribution and follow-up process. The near-complete response rate enhances the reliability and representativeness of the result, providing a foundation for analyzing architectural adaptation strategies to address flooding challenges in the study area. This high participation level underscores the importance and relevance of the research topic to the respondents, further validating the study's conclusions and recommendations.

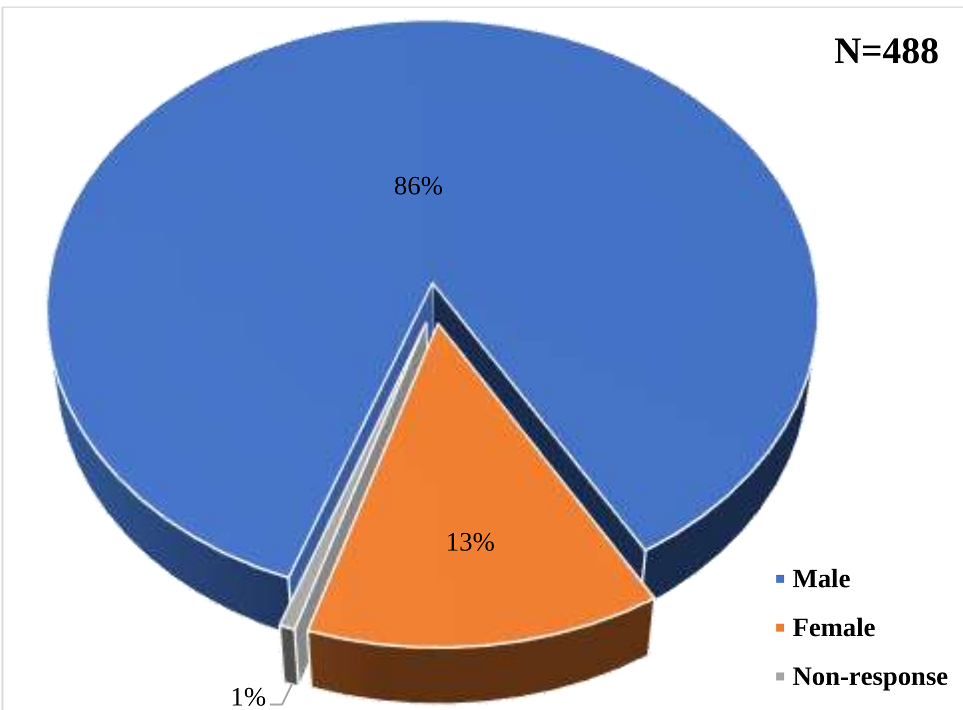

Fig. 7: Percentage Distribution of Gender of Respondents
(Source: Generated by Researcher)

The gender distribution of respondents in the study on architectural adaptation strategies to mitigate perennial pluvial floods in Port Harcourt Metropolis, however, the result reveals a notable disparity, with a higher proportion of male participants. Specifically, 86% of the respondents were male, while 13% were female, and 1% did not provide gender information. This data suggests that men were more likely to engage with the topic of flooding and architectural solutions in the region. Various factors, such as societal roles, cultural norms and the specific nature of this research, may have contributed to the higher male representation in the study.

The relatively small percentage of female participants highlights potential gaps in gender representation when discussing environmental and urban challenges like flooding. Women, particularly in many communities, often play vital roles in resilience building and addressing environmental issues and their perspectives may offer critical insights into the challenges posed by floods. The underrepresentation of women could result in missing views on important factors such as household safety, community engagement, and the role of women in flood mitigation strategies. Future studies may consider developing targeted outreach approaches to encourage more female participation, ensuring a more comprehensive understanding of the impact of floods on various demographic groups.

Additionally, the 1% non-response rate for gender is minimal but underscores the importance of complete participation in demographic data collection. The gender distribution in this research suggests that, although the study predominantly reflects male perspectives, efforts should be made to balance the participation of men and women. Thus, in fostering a more inclusive research environment, future studies can ensure that the voices of both genders are adequately represented in the design and implementation of flood mitigation strategies, which ultimately contribute to creating more resilient communities in Port Harcourt Metropolis.

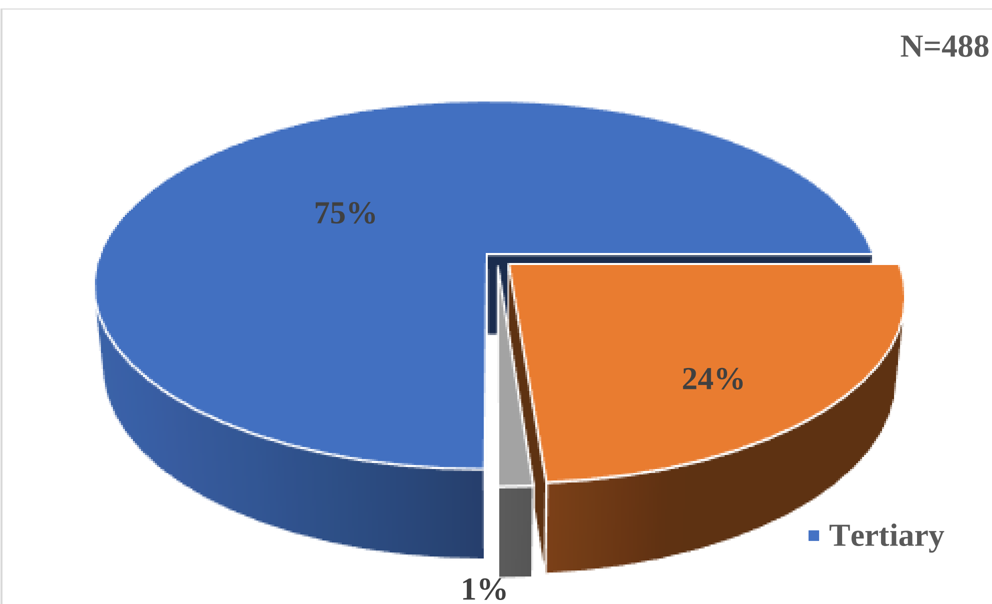

Fig. 8: Percentage Distribution of Educational Attainment
(Source: Generated by Researcher)

In Figure 8 showed the Percentage Distribution of Educational Attainment. However, a large proportion of the respondents, 75%, hold tertiary education. This suggests that most individuals in the sample are well-educated, which likely enhances their ability to grasp complex issues such as urban flooding, sustainable development, and the technical aspects of flood mitigation. This group may also be more inclined to support scientifically grounded solutions and policies related to urban planning and infrastructure. A substantial 24% of respondents have completed secondary education. While this group may not have the in-depth technical knowledge of those with tertiary education, they likely possess general awareness about urban environmental issues. Their opinions and insights could be shaped by broader societal conversations and awareness campaigns regarding flooding and urban resilience. They may offer practical ideas based on their experiences and observations in their communities. A smaller percentage, 1%, has only completed primary education. Despite their limited formal education, this group may still provide important perspectives, particularly based on lived experiences of flooding and its impacts on everyday life. Their insights might emphasize simple, accessible solutions or community-driven approaches to address flooding in a way that does not require specialized knowledge. Additionally, the data indicates a relatively well-educated sample, predominantly consisting of individuals with tertiary or secondary education. This educational background is likely to influence their ability to contribute to discussions on the challenges and potential solutions for perennial flooding in the region. However, it is essential to include the perspectives of all education levels, ensuring that both expert and community-based knowledge contribute to the design of effective flood mitigation strategies.

The Impact of Perennial Pluvial Flooding on the Architectural Quality and Performance of Buildings in Port Harcourt

Table 1: Main Reason Some Areas Experience Severe Flooding

S/N	**Reason**	**Response**		
		Yes	**No**	**Total**
1.	Overwhelmed drainage systems	99.8	0.2	**100**
2.	Impermeable ground surfaces (that don't allow water to pass through)	91.4	8.6	**100**
3.	Intense rainfall	98.0	0.2	**100**
4.	Climate change	95.5	4.5	**100**

Source: Researcher, 2024

Table 4.11 presents the main reasons or reveals key factors contributing to severe flooding in certain areas. Overwhelmed drainage systems were identified by 99.8% of respondents as the primary cause, indicating that insufficient or inadequate drainage infrastructure is a major contributor to flooding. A significant 91.4% highlighted impermeable ground surfaces, such as concrete and asphalt, that prevent water absorption. Intense rainfall was also recognized by 98.0% as a leading factor, emphasizing the role of heavy downpours in exacerbating flooding. Additionally, 95.5% of respondents attributed flooding to climate change, suggesting that changing weather patterns are influencing flood severity. These findings point to a combination of infrastructure challenges and environmental changes as the main drivers of severe flooding.

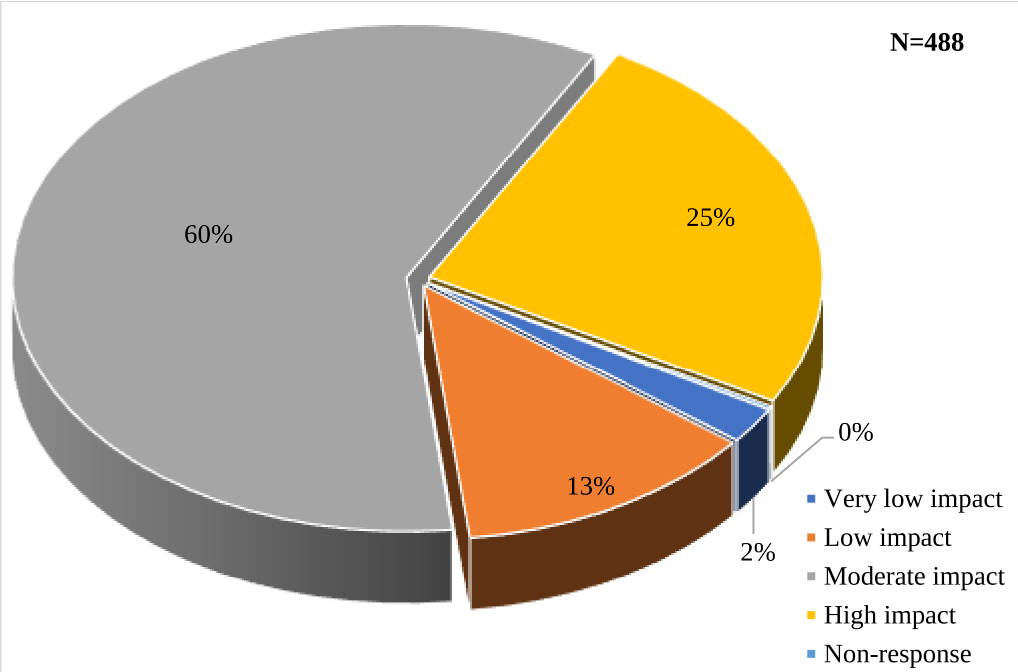

Fig 9: Rating of Impact of Perennial Pluvial Flooding on the Safety of Buildings in the Affected Area.
(Source: Source: Researcher, 2024)

Figure 9 presents respondents' rating of the impact of perennial pluvial flooding on the safety of buildings in the affected area. However, the survey results on the impact of perennial pluvial flooding on the safety of buildings in the affected area present an interesting distribution of opinions. The largest portion of respondents (60%) categorized the impact as moderate. This suggests that, while the flooding is an issue, it is not universally viewed as a major threat. Respondents who selected this option likely feel that flooding has noticeable consequences on the structural integrity of buildings, such as water damage or foundation issues, but may not pose an immediate or severe risk to safety. Meanwhile, 25% of participants assessed the impact as high, indicating that a significant portion of the population views the flooding as a serious concern for building safety. This group likely believes the effects of flooding, such as erosion or water seepage, are substantial enough to threaten the safety of structures in the area. This perception of a high impact could be tied to more frequent or intense flooding events that are undermining the stability of buildings, making this a critical issue for many. On the opposite end of the spectrum, 13% of respondents considered the flooding are impact to be low, and just 2% rated it as very low. These individuals might live in areas less frequently affected by flooding, or they may believe that the buildings in their area are sufficiently resilient to handle such conditions. As a result, they may not see flooding as a significant threat to safety.
Interestingly, there were no non-responses, suggesting that every participant in the survey felt strongly enough about the issue to offer an opinion. This level of engagement reflects the

community's awareness of the risks associated with flooding and the perceived need to address its effects on building safety. Furthermore, while the majority of respondents (60%) perceive the impact of flooding as moderate, a significant portion (25%) views it as a high risk to building safety. This indicates that while some see the flooding as manageable, many consider it a pressing concern that may require intervention. The low percentages of those who downplay the issue further emphasize the widespread acknowledgment of flooding's potential to compromise the safety of buildings in the affected area.

The Impact of Perennial Pluvial Flooding on the aesthetic Quality of Buildings. The result indicates that a small portion (5%) of buildings experiences minimal impact, indicating that some structures are better equipped to withstand flood effects, possibly due to their design, materials, or location in less vulnerable areas. However, the majority of respondents (80%) reported moderate damage, reflecting widespread yet less severe aesthetic issues, such as water stains, discoloration and minor erosion, which collectively degrade the visual appeal of buildings over time. Meanwhile, 15% of respondents reported significant damage, such as structural cracks, peeling paint, and severe corrosion, highlighting the more extreme consequences of persistent flooding. This distribution underscores the pervasive yet variable impact of pluvial floods, emphasizing the need for proactive measures to prevent long-term deterioration and maintain the aesthetic value of buildings in flood-prone areas.

Table 2: Comfort level within buildings is unbearable during or after flooding events

comfort level within buildings is unbearable during or after flooding events		
Responses	**Frequency (F)**	**Percentages (%)**
Strongly Agree	42	9%
Agree	74	15%
Neutral	23	5%
Disagree	192	39%
Strongly Disagree	157	32%
Total	**488**	**100%**

Source: Researcher, 2024

Table 2, provides insight into respondents' perceptions of comfort levels within buildings during or after flooding events. A significant majority of respondents, comprising 39% who disagreed and 32% who strongly disagreed, collectively accounting for 71%, do not consider the comfort level within buildings unbearable during or after flooding. This suggests that for most individuals, buildings might provide adequate protection or comfort during such events, or they may have adapted to the conditions to an extent that discomfort is not perceived as severe. On the other hand, a smaller portion of respondents, totaling 24%, either agreed (15%) or strongly agreed (9%) that the comfort level within buildings becomes unbearable. This minority may represent individuals whose living conditions or building structures are more severely affected by flooding, leading to greater discomfort. Such experiences could stem from factors like inadequate drainage, poor building materials, or prolonged exposure to flooding effects. Furthermore, a minimal 5% of respondents remained neutral, indicating that they neither agreed nor disagreed with the statement. This neutrality could reflect indifference, lack of direct experience, or uncertainty about the extent of discomfort caused by flooding events. In summary, the results highlight that while a significant majority of respondents do not find comfort levels unbearable during or after flooding, a smaller but notable proportion experiences discomfort. This disparity underscores the need for targeted interventions to address the specific challenges faced by those significantly affected by flooding in their buildings.

The survey results show a generally favorable yet cautious view among respondents. A large majority (73%) consider the buildings to be somewhat durable, suggesting that most people believe the structures are fairly stable and resilient. This indicates that the buildings are generally viewed as solid, likely due to adequate construction or maintenance, although there may be recognition that some level of upkeep is required to ensure their long-term durability. In contrast, 11% of respondents feel that the buildings are not durable. These individuals may be concerned about factors such as poor quality of construction, aging materials, or insufficient care that could lead to the deterioration of the buildings over time. Additionally, 12% of respondents were neutral or undecided, possibly due to a lack of concrete information or direct experience with the buildings' performance. This suggests that for some, the issue of durability may not have been a significant concern or they might not have sufficient data to form an opinion. Only 4% of respondents believe the buildings are highly durable, which reflects a perception that some of the structures are built with superior quality materials or construction methods, leading to greater long-term reliability. In addition, while most respondents regard the buildings as somewhat durable, the results indicate that concerns about durability remain, especially regarding the need for ongoing maintenance. This suggests a general satisfaction with the buildings' durability but also points to areas where improvements could be made to enhance their long-term resilience.

Discussion of Findings

Finding on the key factors contributing to severe flooding in the study areas identify overwhelmed drainage systems 99.8% as the main contributing factors by the respondents, highlighting inadequate drainage infrastructure as a major cause. Impermeable ground surfaces, such as concrete and asphalt, were noted by 91.4% of respondents, which hinder water absorption. Intense rainfall was recognized by 98.0% as a significant factor, emphasizing its role in flooding. Additionally, 95.5% attributed flooding to climate change, suggesting that altered weather patterns are exacerbating flood events. These findings underscore the need for improved drainage and urban planning, alongside addressing climate change impacts. Findings on the impact of perennial pluvial flooding on the safety of buildings in the affected study area reveal that the majority of respondents (60%) consider the impact of perennial pluvial flooding on building safety to be moderate, indicating noticeable but not severe effects. A significant portion (25%) view the impact as high, suggesting concerns over the serious threat flooding poses to structural integrity. Meanwhile, 13% perceive the impact as low, and just 2% see it as very low, likely due to less frequent flooding or resilient structures. No non-responses were recorded, reflecting the community's strong awareness of the issue and the general recognition of flooding's potential risk to building safety. Findings on the aesthetic impact of perennial pluvial floods on buildings, shows that 5% of the respondents reported minimal impact, likely due to flood-resilient designs and favorable locations, the majority (80%) experienced moderate effects, such as water stains and discoloration, which degrade building appearances over time. Additionally, 15% noted significant damage, including structural cracks and severe corrosion, highlighting the severe effects of persistent flooding in some areas. These findings emphasize the widespread but variable impacts of pluvial floods and underscore the importance of flood prevention and maintenance measures to preserve the aesthetic and structural integrity of buildings.

Findings on the perceptions of comfort levels in buildings during and after flooding shows that majority (71%) of respondents, including 39% who disagreed and 32% who strongly disagreed, believe buildings provide adequate comfort and have adapted to flooding conditions. Conversely, 24% (15% agreed, 9% strongly agreed) reported unbearable discomfort, likely due to inadequate drainage, poor building materials and prolonged flooding exposure. A small neutral group (5%) indicated indifference and uncertainty. Thus, while most respondents do not perceive significant discomfort, the experiences of those severely affected emphasize the need for targeted measures to improve building resilience and address flooding challenges. Finding on the Durability of Buildings show that 73% of respondents consider the buildings somewhat durable, indicating general satisfaction with their stability and resilience. However, 11% perceive the buildings as not durable, likely due to concerns about construction quality or aging materials. A small percentage (12%) was neutral or undecided, possibly due to lack of information or experience with the buildings' performance. Only 4% view the buildings as highly durable, suggesting that these structures may be seen as exceptionally resilient. Overall, the majority feel the buildings are relatively durable, but concerns about maintenance and longevity persist.

Conclusion

This study has explored the impact of perennial pluvial flooding on the architectural quality and performance of residential buildings in selected areas of Port Harcourt Metropolis, considering safety, functionality, aesthetics, comfort, and durability. The research utilized a mixed-methods approach, combining primary data collection through surveys, interviews, and field observations with an extensive review of existing literature. The findings underscore the necessity for an integrated flood mitigation approach that encompasses architectural adaptations, comprehensive urban planning, and robust governance frameworks. The impact on infrastructure revealed widespread issues, with 95.7% identifying health risks from contaminated water and 79.3% noting property damage. Architectural quality was also affected, as 60% of respondents rated the safety impact of flooding as moderate, while aesthetics suffered due to water stains and structural corrosion reported by 80% of respondents. Regarding comfort, 71% felt buildings were moderately adapted, although a minority reported significant discomfort. Durability was deemed satisfactory by 73%, but concerns over aging materials and poor maintenance persisted.

Recommendations

i. The study recommends the implementation of Blue-Green Infrastructure (BGI) in residential buildings. BGI combines natural systems with urban planning to reduce storm water runoff, improve water quality, and enhance urban livability. This guide provides practical guidance on implementing BGI in residential buildings, with the aim of promoting flood resilience and creating more sustainable and resilient communities. It applies to new and existing residential buildings in Port Harcourt Metropolis

ii. The study proposed a flood-resilient design framework that incorporates architectural innovations, effective stakeholder involvement, and strong policy measures. Thus in enhancing public awareness, fostering community participation, and prioritizing sustainable urban planning practices, Port Harcourt Metropolis can better manage and mitigate the impacts of perennial pluvial floods while building a more resilient urban environment.

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