Flooding Areas in Port Harcourt Metropolis: Vulnerability to Perennial Pluvial Flooding Experience

Okey-Ejiowhor, Caleb H., Pepple, Tonye D., PhD and Edwin, Anthony D, PhD
Rivers State University, Faculty of Environmental Sciences,
Department of Architecture
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Abstract
Perennial pluvial flooding presents significant challenges to the urban environment of Port Harcourt Metropolis, impacting infrastructure, public health, and overall urban functionality. This study examined flooding areas in Port Harcourt Metropolis: Vulnerability to perennial pluvial flooding experience. Blue-Green Infrastructure (BGI) 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 highlight highly vulnerable areas, such as Rumuewhara New Layout/Eneka (elevation 17.1m) and NTA/Apara Link Road (elevation 13.5m), where floodwaters can reach depths of up to 200mm. Over 90% of respondents identified streets in Obio/Akpor Local Government Area (LGA) as the most affected in the metropolis. Moderately and low-flooded areas display community-driven mitigation efforts, such as flood barriers, but government strategies are found to be lacking. The study recommends a comprehensive Flood Resilient Design Framework (FRDF) involving a multi-faceted approach to mitigate perennial pluvial floods in Port Harcourt Metropolis, including architectural adaptations, urban planning and policy changes, community engagement, and infrastructure development.

Keywords: Flooding Areas, Port Harcourt Metropolis, Vulnerability, Perennial Pluvial Flooding

INTRODUCTION

A flood is the accumulation of too much water which rises to overflow land which is not normally submerged (Mukhopadhyay, 2010; Ward, 1978). Flooding can comprise overflow of a river as a result of prolonged seasonal rainfall, rainstorm, 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 intrusion of sea water onto coast lands during cyclonic/tidal surges (Stoltman, Lidstone, & DeChano, 2004). The terms used to describe flooding are numerous and may mean different things to different scholars with respect to the context in which they are used (Brooks, 2003; Brooks, Adger, & Kelly, 2005). Social scientists and climate scientists often mean different things when they use the term “vulnerability”; whereas social scientists tend to view vulnerability as representing the set of socio-economic factors that determine people’s ability to cope with stress or change (Allen, 2003; Okey- Ejiowhor, Amakiri, & Nkeiruka, 2022). Climate scientists often view vulnerability in terms of the likelihood of occurrence and impacts of weather- and climate-related events (Fussel & Klein, 2006; Hinkel, 2011; Malone & Engle, 2011; Nicholls, Hoozemans, & Marchand, 1999; Vincent, 2004; Yusuf & Francisco, 2009). Vulnerability as used in this work is those biophysical and socio-economic factors that determine people's ability to cope with flooding.

Climate change manifests through rising sea levels, desertification, crop failure, and flooding, all of which pose significant threats to humanity (United Nations Human Settlements Programme [UN-Habitat], 2020). These impacts, particularly perennial flooding, are evident in the Port Harcourt Metropolis, Rivers State. Additionally, in Port Harcourt Metropolis, pluvial flooding accounts for 41% of flooding incidents nationwide (Terence, Ayodele & Samuel, 2020). However, understanding the types and causes of flooding provides clarity for detecting the problems associated with perennial pluvial flooding and identifying architectural adaptation strategies to mitigate its impacts. Therefore, this study seeks to analyze the determinants of flooding in Port Harcourt Metropolis, focusing on architectural adaptation strategies to mitigate and curtail perennial pluvial flooding.

Studies on vulnerability to climate change and climate risks, including floods, have been undertaken in different regions of the world (Ali, 2007; Aragon-Durand, 2007; Bankoff, 2003; Dutta, Khatun, & Herath, 2005; Gbetibouo & Ringler, 2009; Heltberg & Bonch-Osmolovskiy, 2011; Metzger & Schroter, 2006; Midgley et al., 2011; Thieken, Kreibich, & Merz, 2007; Thorton et al., 2006; Yusuf & Francisco, 2009). Some excellent conceptual and applied work has emerged in the fields of climate change vulnerability and adaptation (Adger, 2006; Fussel & Klein, 2006; Smit & Wandel, 2006; Vincent, 2004). However, it has been challenging to convert conceptual and qualitative approaches into a quantitative index of vulnerability (Hinkel, 2011). Climate risk and vulnerability mapping have been conducted mostly for the developed countries, but in developing countries, there however exists a gap in the knowledge of vulnerability and coping capacities of African societies to flood hazards, where many of recorded flood disasters are consequences of natural hazards aggravated by development flaws in affected communities (Adelekan, 2010; Olorunfemi, 2011; Amakiri, Nkeiruka, & Okey-Ejiowhor, 2022).

Nigeria is not an exception; knowledge is still sparse in the literature on flood vulnerability mapping in the country. However, some studies have been carried out on flood vulnerability assessment in some Nigerian areas using different approaches (Ologunorisa, 2004; Ishaya, Ifatimehin, & Abaje, 2009; Ologunorisa, 2004). Thecla and Chinedu (2015) acknowledged that the study approach of Ologunorisa (2004) was basically an assessment of flood vulnerability zones in the Niger Delta using hydrological techniques based on some measurable physical characteristics, whereas Ishaya et al. (2009) mapped areas vulnerable to flood hazard in Gwagwalada urban area of Abuja using Landsat™ image of 1991 and 2001. Adelekan (2010) approach was based on using the vulnerability characteristics of people to assess the disastrous Abeokuta flood that occurred in 2007. Hitherto, none of these studies provides information on the integrated flood assessment in any part of the country. This is unfortunate, because it has increasingly been acknowledged that an area like the Niger Delta region, which experiences perennial floods owing to its location and low-lying topography, and heavy rainfall (Ogba & Utang, 2008; Ologunorisa & Abawua, 2005), should have been assessed using the integrated method. Port Harcourt is one of such areas considered to be vulnerable to flooding (Oku, Wichendu, & Poronaike, 2011). In 2006, Port Harcourt experienced an unprecedented flooding which submerged houses, paralyzed economic activities, and rendered some people internally displaced in some zones (Zabbey, 2006; Dimkpa, Ohochuku, Adibe, & Okey-Ejiowhor, 2024). Hence in systematically reviewing the challenges faced by residents, this study aimed to Identify the areas within Port Harcourt Metropolis that are most vulnerable to perennial pluvial flooding.

LITERATURE REVIEW

The Concept of Flooding

Oxford Dictionary defines a flood as an overflow of a large amount of water beyond its normal limits, especially over what is normally dry land. A flood is the accumulation of too much water which rises to overflow land that is not normally submerged (Mukhopadhyay, 2010). 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.

Types of Flooding

Coastal (Surge) Floods

A coastal flood, as the name suggests, occurs in areas that lie on the coast of a sea, ocean, or other large body of open water. It is typically the result of extreme tidal conditions caused by severe weather. Storm surge produced when high winds from hurricanes and other storms push water onshore is the leading cause of coastal flooding and often the greatest threat associated with a tropical storm. In this type of flood, water overwhelms low-lying land and often causes devastating loss of life and property (Maddox, 2021)

Coastal flooding is categorized into three levels:

1. Minor: A slight amount of beach erosion will occur but no major damage is expected.
2. Moderate: A fair amount of beach erosion will occur as well as damage to some homes and businesses.
3. Major: Serious threat to life and property. Large-scale beach erosion will occur, numerous roads will be flooded, and many structures will be damaged. Citizens should review safety precautions and prepare to evacuate if necessary.

The severity of a coastal flood is determined by several factors, including the strength, size, speed, and direction of the storm. The onshore and offshore topography also plays an important role. To determine the probability and magnitude of a storm surge, coastal flood models consider this information in addition to data from historical storms that have affected the area, as well as the density of nearby development.

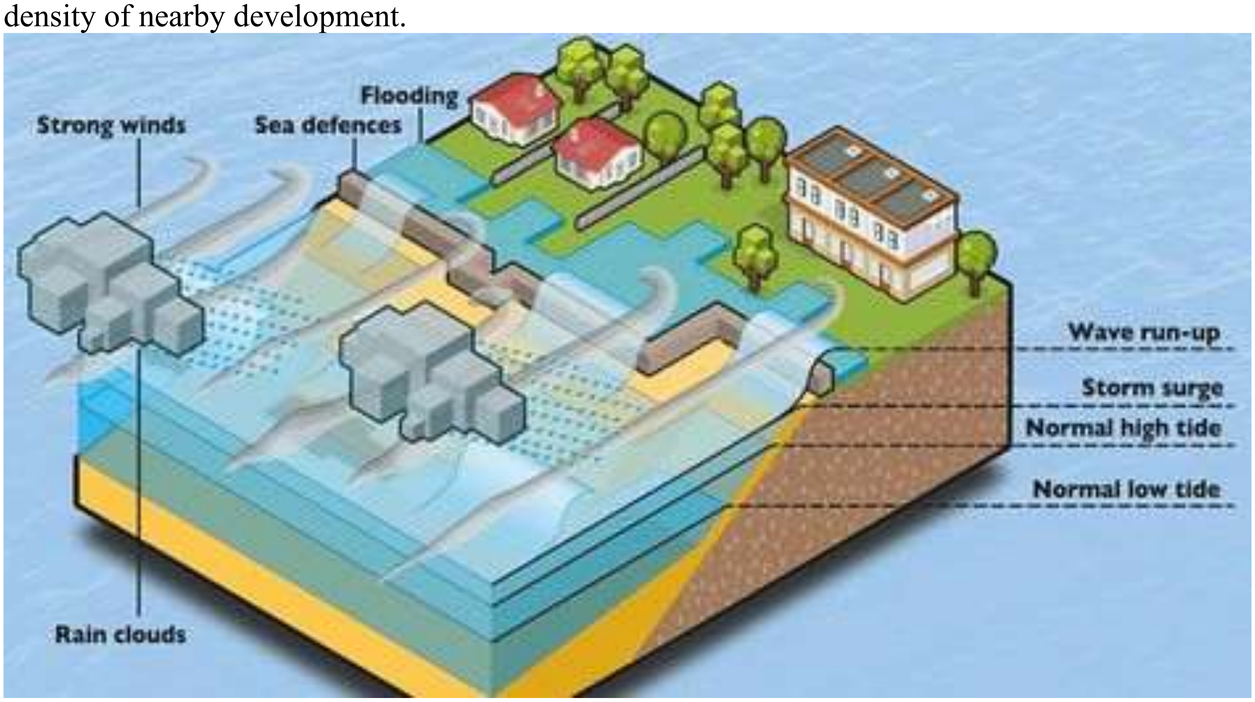

Figure 1: Coastal Flood Diagram. Source: Gillilard, (2017).

Fluvial (River) Floods

Fluvial or riverine flooding, occurs when excessive rainfall over an extended period causes a river to exceed its capacity. It can also be caused by heavy snow melt and ice jams. The damage from a river flood can be widespread as the overflow affects smaller rivers downstream, often causing dams and dikes to break and swamp nearby areas (Maddox, 2021)

There are two main types of riverine flooding:

1. Overbank flooding occurs when the water rises and overflows over the edges of a river or stream. This is the most common and can occur in any size channel — from small streams to huge rivers.
2. Flash flooding is characterized by an intense, high-velocity torrent of water that occurs in an existing river channel with little to no notice. Flash floods are very dangerous and destructive not only because of the force of the water but also the hurtling debris that is often swept up in the flow.

The severity of a river flood is determined by the amount of precipitation in an area, how long it takes for precipitation to accumulate, the previous saturation of local soils, and the terrain surrounding the river system. In flatter areas, floodwater tends to rise more slowly and be more shallow, and it often remains for days. In hilly or mountainous areas, floods can occur within minutes after heavy rain. To determine the probability of river flooding, models consider past precipitation, forecasted precipitation, current river levels, and temperatures.

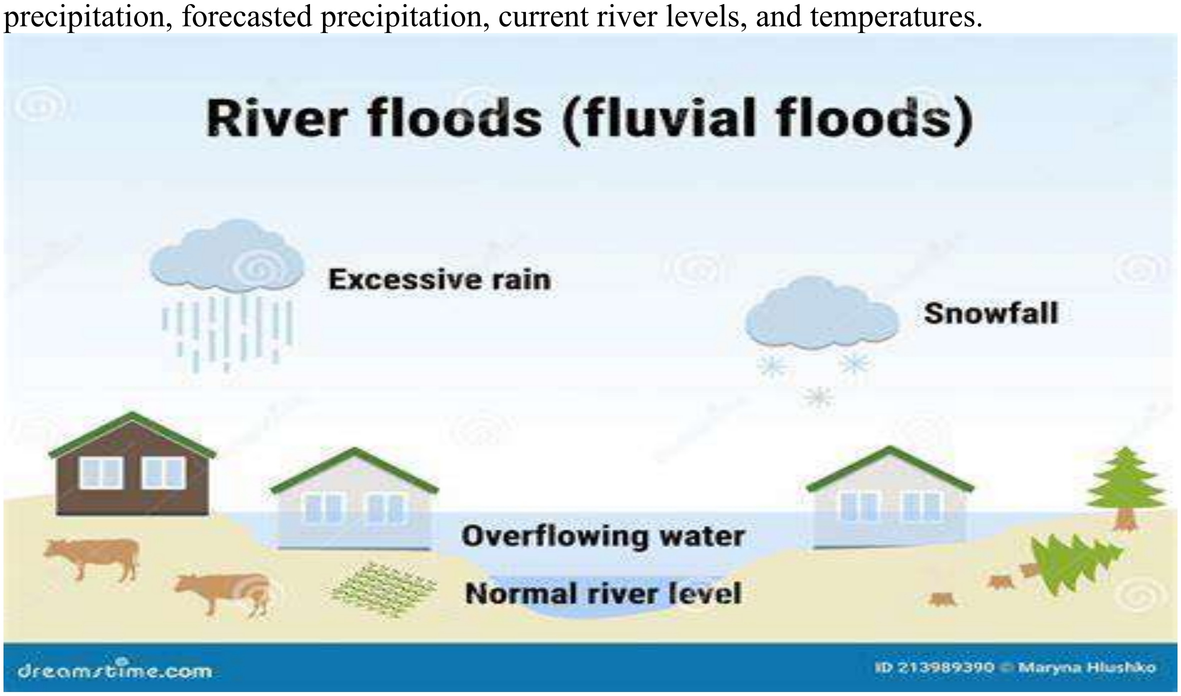

Figure 2: Depiction of River Floods (Fluvial Floods). Source: Maryna Hlushko, (2021).

Groundwater Floods

Groundwater flooding is a lesser-known type of flooding. It is the emergence of groundwater at the ground surface away from perennial river channels and can also include the rising of groundwater into man-made ground, including basements and other subsurface infrastructure. (Macdonald et al., 2012) Flooding from groundwater can happen when the level of water within the rock or soil underground – known as the water table – rises. When the water table rises and reaches ground level, water starts to seep through to the surface and flooding can happen. This means that water may rise up through floors or underground rooms such as cellars or basements. Water doesn't always appear where you would expect it to - such as valley bottoms – it may also emerge on hillsides (*What Is Groundwater Flooding?*, 2019). Groundwater flooding takes much longer to develop than river flooding, often appearing days, weeks, or even months after heavy or prolonged rainfall. This type of flooding can persist for weeks or even months. It is most common in areas with chalk bedrock but can also occur in places with sand and gravel, like river valleys.

To understand groundwater and basement floods, one needs to first understand groundwater. An estimated $40km^3$ of water runs across the surface of the earth per year, some of it gets collected in surface reservoirs like rivers and streams that flow back into the ocean while the rest seeps into the ground to recharge groundwater systems or aquifers. There is about 35 times as much water that seeps into the groundwater systems than there is in surface reservoirs. With the increase in frequency and duration of rainfall due to climate change, groundwater aquifers increase in size by absorbing more water. With increased groundwater comes higher groundwater table or artesian conditions. If the groundwater table exists behind a basement wall, then the wall will be subject to hydrostatic pressure which can force large quantities of water through wall cracks or joints and lead to basement flooding (Brisibe et al., 2021).

Pluvial (Surface) Floods

Pluvial or surface water flooding occurs when intense rainfall overwhelms the natural or man-made drainage systems, causing water to accumulate on the surface rather than flowing into rivers or other water bodies. This form of flooding is typically independent of overflowing water bodies and is often associated with extreme precipitation events, which have been increasingly recognized as a growing hazard in many urban areas (Kundzewicz, Hoozemans & Svensson, 2022). Unlike traditional flood risks, pluvial flooding can impact even elevated areas that are not directly near rivers or coastal zones, challenging the common misconception that flood risks are limited to proximity to water bodies (Maddox, 2021).

There are two primary types of pluvial flooding:

1. Saturated Drainage Systems: In urban environments, heavy rainfall can exceed the capacity of drainage systems, causing water to overflow onto streets and properties. This is most common in areas where rainfall intensity surpasses the designed capacity of urban stormwater systems, leading to localized flooding (Núñez, Fernandez & Gómez, 2021).

2. Runoff from Impermeable Surfaces: When rain falls on hard, impermeable surfaces like asphalt or concrete, water cannot be absorbed into the ground. This runoff can quickly accumulate, leading to surface flooding, particularly in densely built-up areas (Piroozfar, Sarlak & Erdem, 2020).

Pluvial flooding frequently interacts with other forms of flooding, such as coastal and riverine floods, exacerbating the overall flood risk. Although pluvial floods are typically shallow, even a few centimeters of water can cause significant damage to property and disrupt daily life. While this type of flooding is distinct from flash flooding often caused by rapid runoff from a river or stream both types share similar causes in terms of high-intensity rainfall (Falconer, Smith & Jones, 2022). In particular, the frequency of these rainfall events appears to be rising, which may be linked to broader climate change patterns, leading to more frequent and severe flood events in urban centers (World Bank, 2023).

The Niger Delta region, including Port Harcourt Metropolis, is particularly vulnerable to pluvial flooding due to its low-lying topography, intense rainfall, and urbanization. Various studies have highlighted that a combination of environmental factors, such as land-use changes, deforestation, and urban sprawl, contribute to the severity of pluvial floods in this region (Kenny, Booth & Austin, 2021). Notably, while rainfall is a key driver of these floods, it is often the result of a complex interplay of topographical and anthropogenic factors that exacerbate the flood risk.

In response to these recurring flood events, Nigeria has taken steps to address disaster management through the National Emergency Management Agency (NEMA), established by the NEMA Act (12 as amended by Act 50 of 1999). NEMA is tasked with disaster response, policy formulation, risk assessment, and providing relief efforts. The agency's focus extends to areas at risk of pluvial flooding, working alongside state-level entities such as the Rivers State Emergency Management Agency (SEMA) to mitigate flood-related hazards (Ogu & Adekola, 2022). Understanding flood-prone areas is essential to creating effective prevention and mitigation strategies, a task which requires collaboration between government bodies and local communities.

Flood in 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).

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 3: Flooding of Federal Road Safety Commission Port Harcourt Office along Aba Road.
The 2021 Floods in Port Harcourt

Residents reported that on 21st September 2021, the capital city of Rivers State, Port Harcourt, experienced severe flooding due to torrential rains. Among the most impacted were the Federal Road Safety Corps (FRSC) office and the Port Harcourt Shopping Mall (SPAR). The rains, which began at dawn and continued for several hours, overwhelmed the FRSC's Port Harcourt Zonal Office on Aba Road. Business operations at SPAR were heavily disrupted as staff scrambled to protect merchandise from floodwater that submerged the ground floor of the mall on Azikiwe Road. Numerous cars were also submerged on major roads throughout the city, leaving many commuters stranded and residents facing significant property losses. Several respondents and victims blamed the flooding on inadequate drainage systems in the city. Additionally, some criticized the Rivers State Government for the rapid and concurrent construction of road projects concentrated in the capital city and the reclamation of waterways that previously absorbed floodwater. The most affected areas included Station Road, Abali Motor Park, Rivers State Judiciary Complex, Ikwerre Road, Ada George, and Sanni Abacha Road. One resident highlighted that the government's unrestrained land reclamation on waterways that used to absorb floodwater had exacerbated the situation. They remarked, the water will always find its level. The result is what we are seeing now. The affected areas may have been prone to flooding in the past, but the experience today is unprecedented (Vanguard, 2021)

Ultimately, the consensus among many was that urbanization and the indiscriminate construction over natural waterways were the primary causes of the severe flooding in Port Harcourt.

Plate 4: **Flooding of Port Harcourt Mall Flood along Azikiwe Road. Source**: Vanguard Newspaper, (2021)

Architectural Adaptation Strategies

To mitigate the impacts of perennial pluvial flooding in Port Harcourt Metropolis, researchers have proposed various architectural adaptation strategies that are largely Structural measures. Permeable pavements, for example, have been identified as an effective strategy for reducing surface runoff and increasing infiltration (Efe & Opoko, 2020). Blue roofs have also been proposed as a way of reducing runoff, increasing evapotranspiration, and improving thermal performance (Sarai & Oloke, 2021). Other strategies include the use of rain gardens, retention basins, and elevated buildings. Rain gardens are vegetated depressions that collect and filter runoff from impervious surfaces, while retention basins are designed to temporarily store and release stormwater runoff (Enaruvbe et al., 2021). Elevated buildings are designed to raise the ground floor of buildings above flood levels, reducing the exposure of buildings to floodwaters (Akande et al., 2020).

Architecture in general can be adapted to some degree, as buildings can always be modified manually in some manner. Brand's book How Buildings Learn provides insight into the different levels of adaptation that can be expected and how they apply over various periods (Brand, 1994). Therefore, the term Adaptive Architecture must be considered in this broader context, and the distinction between adaptable and adaptive architecture is as follows: Adaptive Architecture refers to buildings that are purposefully designed to adapt, whether automatically or through human intervention, to their environment, occupants, and objects within them (Schnadelbach, 2010). To manage potential climate hazards, such as extreme storms and flooding, that could impact water quality, infrastructure, and safety, the Environmental Resilience Institute in Indiana suggests adaptation strategies. These strategies include the use of green infrastructure techniques to mitigate recurrent flooding. One or more methods may be employed for adaptation purposes (Environmental Resilience Institute, Indiana).

Blue-Green Infrastructure Theory

The study was anchored on Blue-Green Infrastructure (BGI) Theory which advocated for the integration of water management (blue) and vegetative systems (green) to address urban stormwater challenges. It encompasses a range of sustainable urban drainage approaches, including green roofs, rain gardens, bioswales, permeable pavements, retention ponds, and wetlands. These features not only manage stormwater but also deliver ecosystem services like flood mitigation, water purification, and habitat creation (Ahern, 2013; Lennon, 2015). Ahern (2013) emphasizes the multifunctionality of BGI, highlighting its capacity to simultaneously address flooding, enhance biodiversity, and improve urban aesthetics. This is particularly relevant to Port Harcourt, where urbanization has led to the loss of permeable surfaces, exacerbating pluvial flooding. The application of BGI features in architectural designs, such as incorporating green roofs or permeable pavements, can significantly reduce surface runoff and enhance flood management. Further, the treatment train approach, as detailed by Qin, Li & Chen. (2013) and Liu, Li, & Qin, (2014), demonstrates how combining multiple BGI measures can amplify their effectiveness in mitigating flood risks. For instance, rain gardens and bioswales can slow and filter runoff before it enters larger retention systems, ensuring comprehensive stormwater management.

Literature Gap

The literature gap in this empirical review is the lack of research on the effectiveness of architectural adaptation strategies in mitigating perennial pluvial floods in Port Harcourt Metropolis. While the review discusses various architectural adaptation strategies, such as permeable pavements, blue roofs, and underground storage systems, it notes that further research is needed to evaluate the effectiveness of these strategies in the local context.

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.

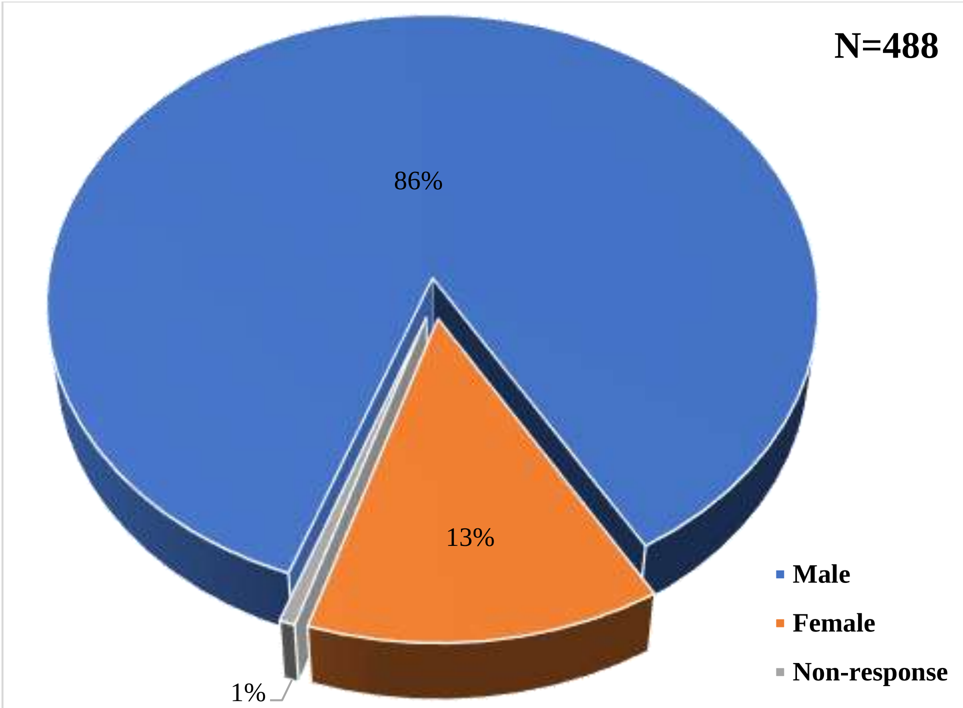

Fig. 5: Percentage Distribution of Gender of Respondents
(Source: Generated by Researcher)

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.

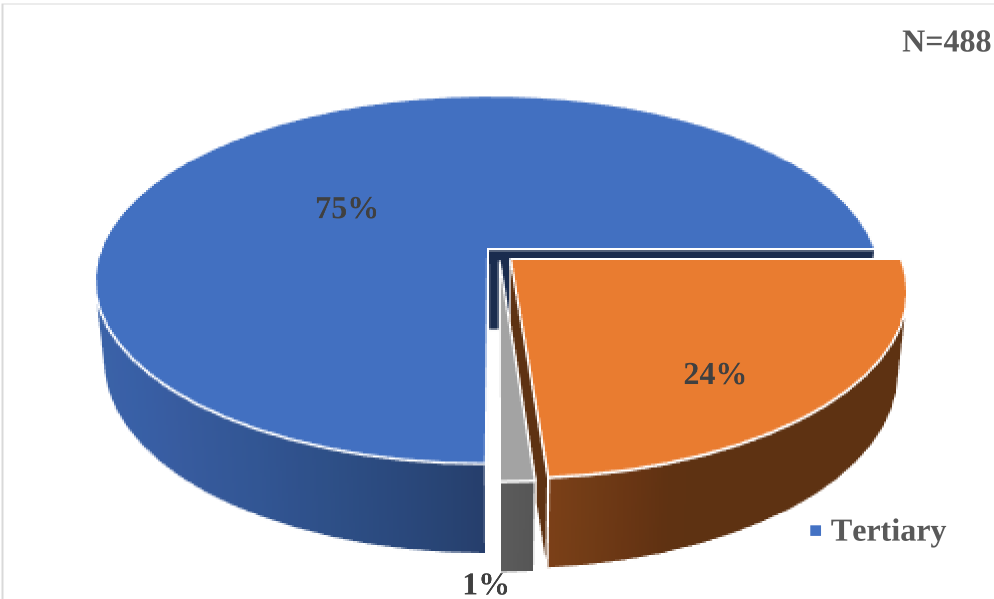

Fig. 6: Percentage Distribution of Educational Attainment
(Source: Generated by Researcher)

In Figure 6 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.

Table 1: Criteria for Classification

Depth of Floodwater	Extent of Floodwater	Classification
20 – 40cm	200 – 400m	Lowly Flooded
41 – 80cm	401 - 600m	Moderately Flooded
Above 80cm	Above 600m	Highly Flooded

(Source: Wizor & Mpigi, 2020**)**

In line with this ex-post facto research, Table 1 shows criteria for classification according to Wizor & Mpigi, (2020), in their research conducted in Port Harcourt Metropolis utilizing Geographic Information System (GIS) technology to identify and map 25 most flooded flood-prone areas categorizing them as lowly, moderately and highly flooded area. However, 8 regions were classified as lowly flooded (20–40 cm; 200–400 m), 9 as moderately flooded (41–80 cm; 401–600 m), and 8 as highly flooded (above 80 cm; Above 600 m); based on the depth of inundation and extent of floodwater. Notably, all identified areas have high population concentrations, emphasizing the urgent need for effective urban planning in Port Harcourt Metropolis and similar cities globally. GIS technology, leveraging tools like GPS and ArcGIS software, proved effective in pinpointing and mapping these areas, and can aid cities in mitigating flood risks and protecting residents.

Table 2: GPS Coordinates of Identified Urban Flood-Prone Areas in Port Harcourt Metropolis

S/No	Name of Street / Road	Northings	Eastings
1	Salem Close, Off Ada George Road	4.855444	6.979556
2	Omachi Road, Rumuodomaya	4.875247	6.999777
3	Abanna Street, Old GRA	4.785583	7.022028
4	Hon. Attah Close, Peter Odili Road	4.793833	7.05075
5	Nkpolu Road 1, Rumuigbo	4.853346	6.986527
6	Eneka Town	4.878167	7.029514
7	Horsefall Street, Old GRA	4.786917	7.021222
8	Evelyn‘s Close, GRA Phase II	4.8195	7.006917
9	Omerelu Street, GRA Phase II	4.839583	7.005639
10	Abacha Road, GRA Phase II	4.823778	7.003361
11	Orubo Close, Peter Odili Road	4.797111	7.052361
12	NTA/Apara Link Road	4.854637	6.983774
13	Obiwali Road, Rumuigbo	4.858639	6.986944
14	L.K. Anga Road, Off Peter Odili Road	4.801917	7.047389
15	Uyo Street, Rumumasi	4.838444	7.017583

16	Odani Road, Elelenwo	4.840208	7.073506
17	Diamond Valley Estate	4.796222	7.046083
18	Rotimi Amaechi Drive, GRA Phase II	4.821278	6.000972
19	BluePearl Street, Peter Odili Road	4.794083	7.019917
20	Hilltop Road, Amadi-Kalagbo	4.823806	7.023444
21	Kenka Road, Off Mgbuoba Road	4.856194	6.980361
22	Akwaka Street, Rumuodomaya	4.880281	6.994285
23	Peter Odili Road	4.804861	7.045556
24	Alalibo Road, Old GRA	4.794083	7.019917
25	Zion Street, Rumuodomaya	4.881607	6.993837

(Source: Wizor & Mpigi, 2020**)**

Table 2 highlight GPS coordinates of flood-prone areas in Port Harcourt Metropolis by Wizor and Mpigi (2020). However, the scholars identify 25 locations that are highly vulnerable to flooding. These areas are distributed across various parts of the metropolis, including Peter Odili Road, Rumuodomaya, Old GRA, and GRA Phase II, among others. The northings and eastings listed in the table indicate a concentration of flood-prone zones between latitudes 4.78°–4.88° and longitudes 6.97°–7.07°, suggesting a clear spatial clustering of affected areas.

Rumuodomaya stands out with several streets such as Omachi Road (4.875247, 6.999777), Akwaka Street (4.880281, 6.994285), and Zion Street (4.881607, 6.993837). The proximity of these coordinates highlights the susceptibility of this area to flooding, likely attributed to rapid urban development and poor drainage systems. Similarly, Peter Odili Road and its adjoining streets, including Hon. Attah Close (4.793833, 7.050750) and Orubo Close (4.797111, 7.052361), have multiple flood-prone locations. The clustering of these areas indicates terrain-related challenges, coupled with insufficient drainage infrastructure. The table also reveals flood-prone streets in Old GRA, such as Abanna Street (4.785583, 7.022028) and Horsefall Street (4.786917, 7.021222). These areas may be prone to flooding due to their low-lying topography and inadequate flood management systems. In GRA Phase II, streets like Abacha Road (4.823778, 7.003361), Evelyn’s Close (4.819500, 7.006917), and Omerelu Street (4.839583, 7.005639) represent a cluster of affected zones. The pattern observed in these high-density neighborhoods highlights how urbanization impacts natural water flow and contributes to flooding.

Additional areas such as Eneka Town (4.878167, 7.029514) and Hilltop Road, Amadi-Kalagbo (4.823806, 7.023444), further illustrate the extent of flood risks in both urban and peri-urban regions. Other vulnerable zones like Rumuigbo (Nkpolu Road 1: 4.853346, 6.986527; Obiwali Road: 4.858639, 6.986944) and Mgbuoba (Kenka Road: 4.856194, 6.980361) reveal how urban growth in these areas, coupled with limited drainage capacity, contributes to persistent flooding problems. Elelenwo’s Odani Road (4.840208, 7.073506) stands out as one of the farthest areas along the eastings, showing that flood issues extend beyond the city center. Furthermore, these results underscore the need for immediate interventions to address urban flooding in Port Harcourt Metropolis. Priority should be given to improving drainage systems, implementing sustainable urban planning policies, and enforcing zoning regulations. Thus, in addressing the root causes of flooding in these identified areas, stakeholders can mitigate its impact on residents and infrastructure.

Table 3: Lowly Flooded Areas in Port Harcourt Metropolis

S/No	Name of Street / Road	Northings	Eastings
1	Abanna Street, Old GRA	4.785583	7.022028
2	Hon. Attah Close, Peter Odili Road	4.793833	7.05075
3	L.K. Anga Road, Off Peter Odili Road	4.801917	7.047389
4	Hilltop Road, Amadi-Kalagbo	4.823806	7.023444
5	Uyo Street, Rumumasi	4.838444	7.017583
6	Omerelu Street, GRA Phase II	4.839583	7.005639
7	Akwaka Street, Rumuodomaya	4.880281	6.994285
8	Peter Odili Road	4.804861	7.045556

Source: Wizor & Mpigi, (2020)

Table 3 highlights the GPS coordinates of eight lowly flooded areas in Port Harcourt Metropolis. These areas, identified by Wizor and Mpigi, are distributed across Old GRA, Peter Odili Road, Rumumasi, GRA Phase II, Rumuodomaya, and Amadi-Kalagbo. The northings and eastings indicate that these areas lie within latitudes 4.78°–4.88° and longitudes 6.99°–7.05°, showing a spatial pattern that suggests relatively less susceptibility to severe flooding compared to other parts of the metropolis.

In Old GRA, Abanna Street (4.785583, 7.022028) stands out as a lowly flooded area. This could be due to its topography or the presence of better drainage infrastructure. Similarly, Hon. Attah Close (4.793833, 7.050750) and L.K. Anga Road (4.801917, 7.047389), both located near Peter Odili Road, are identified as lowly flooded areas. These areas may benefit from their proximity to major roads and better urban planning, reducing their vulnerability to severe flooding. Hilltop Road in Amadi-Kalagbo (4.823806, 7.023444) and Uyo Street in Rumumasi (4.838444, 7.017583) also fall within the category of lowly flooded areas. Their higher elevation or efficient water drainage systems may contribute to reduced flood risks in these locations. Similarly, Omerelu Street in GRA Phase II (4.839583, 7.005639) is less affected by flooding, likely due to its urban planning and infrastructure improvements. Akwaka Street in Rumuodomaya (4.880281, 6.994285) and Peter Odili Road (4.804861, 7.045556) also appear in the list. Despite being located in a region with high urbanization, these areas experience relatively less flooding, suggesting that localized interventions such as proper drainage and flood control measures are effective in mitigating flooding in these specific zones. In addition, the distribution of lowly flooded areas reflects a combination of factors such as elevation, drainage infrastructure, and urban planning. The identification of these zones provides valuable insights for urban planners and policymakers to replicate successful flood mitigation strategies in more vulnerable areas of the metropolis. Furthermore, maintaining and enhancing the existing infrastructure in these lowly flooded areas is critical to ensuring their continued resilience against urban flooding.

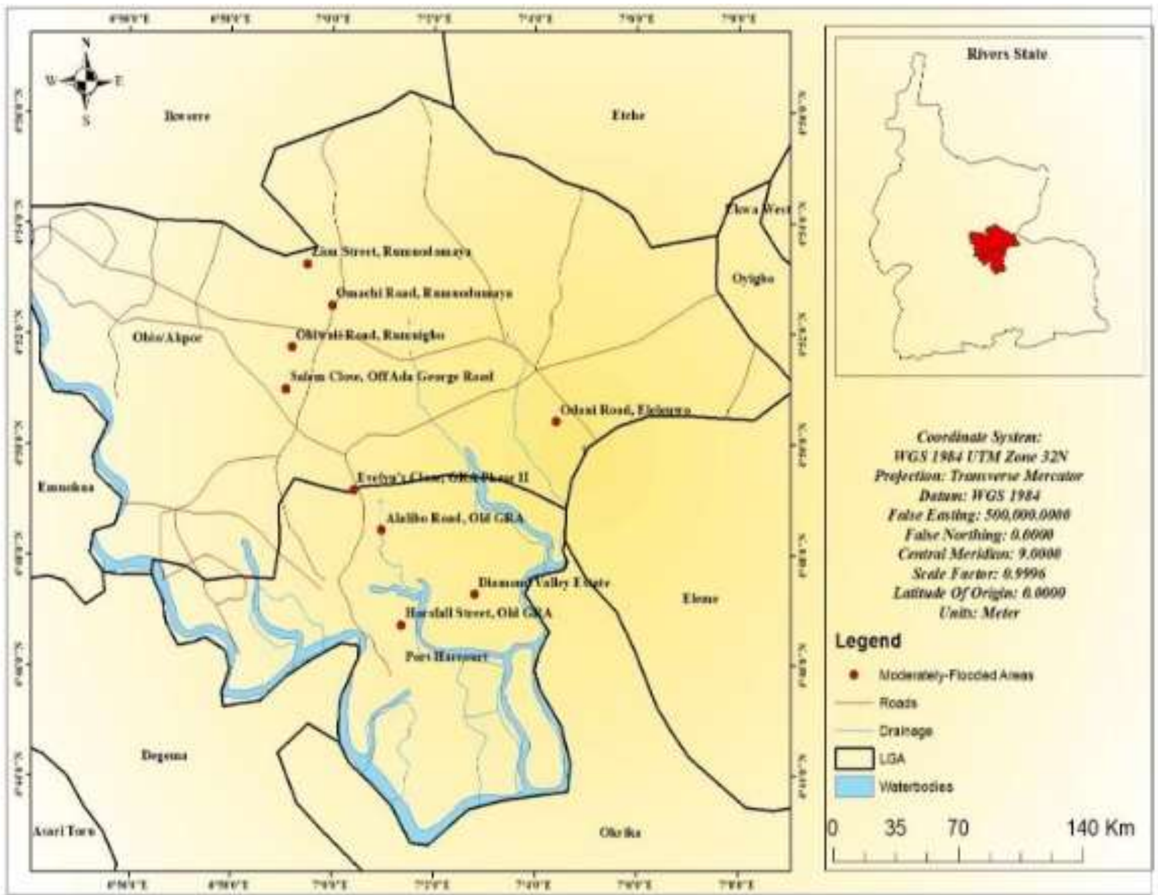

Figure 7: GPS Map of the Moderately Flooded Areas in Port Harcourt Metropolis

(**Source**: Wizor & Mpigi, 2020)

Table 4: Moderately Flooded Areas in Port Harcourt Metropolis

S/No	Name of Street / Road	Northings	Eastings
1	Omachi Road, Rumuodomaya	4.875247	6.999777
2	Salem Close, Off Ada George Road	4.855444	6.979556
3	Obiwali Road, Rumuigbo	4.858639	6.986944
4	Diamond Valley Estate	4.796222	7.046083
5	Zion Street, Rumuodomaya	4.881607	6.993837
6	Odani Road, Elelenwo	4.840208	7.073506
7	Evelyn‘s Close, GRA Phase II	4.8195	7.006917
8	Horsefall Street, Old GRA	4.786917	7.021222
9	Alalibo Road, Old GRA	4.794083	7.019917

Table 4 outlines nine moderately flooded areas within Port Harcourt Metropolis, spread across locations like Rumuodomaya, Ada George Road, Rumuigbo, Elelenwo, GRA Phase II, and Old GRA. These areas are situated within latitudes 4.78°–4.88° and longitudes 6.97°–7.07°. In Rumuodomaya, streets such as Omachi Road (4.875247, 6.999777) and Zion Street (4.881607, 6.993837) experience moderate flooding, potentially due to urban development and insufficient drainage infrastructure. Similar flooding patterns occur at Salem Close off Ada George Road (4.855444, 6.979556) and Obiwali Road in Rumuigbo (4.858639, 6.986944), likely linked to challenges in stormwater management. Diamond Valley Estate (4.796222, 7.046083) and Odani Road, Elelenwo (4.840208, 7.073506) are also affected by moderate flooding, which may stem from proximity to water sources or terrain-related factors. Additionally, Evelyn's Close (4.8195, 7.006917) in GRA Phase II and streets like Horsefall (4.786917, 7.021222) and Alalibo Road (4.794083, 7.019917) in Old GRA face similar flooding challenges. However, these results highlight the necessity of upgrading flood control measures, including effective drainage systems, sustainable urban planning, and water retention structures, to reduce the impact of moderate flooding in these areas.

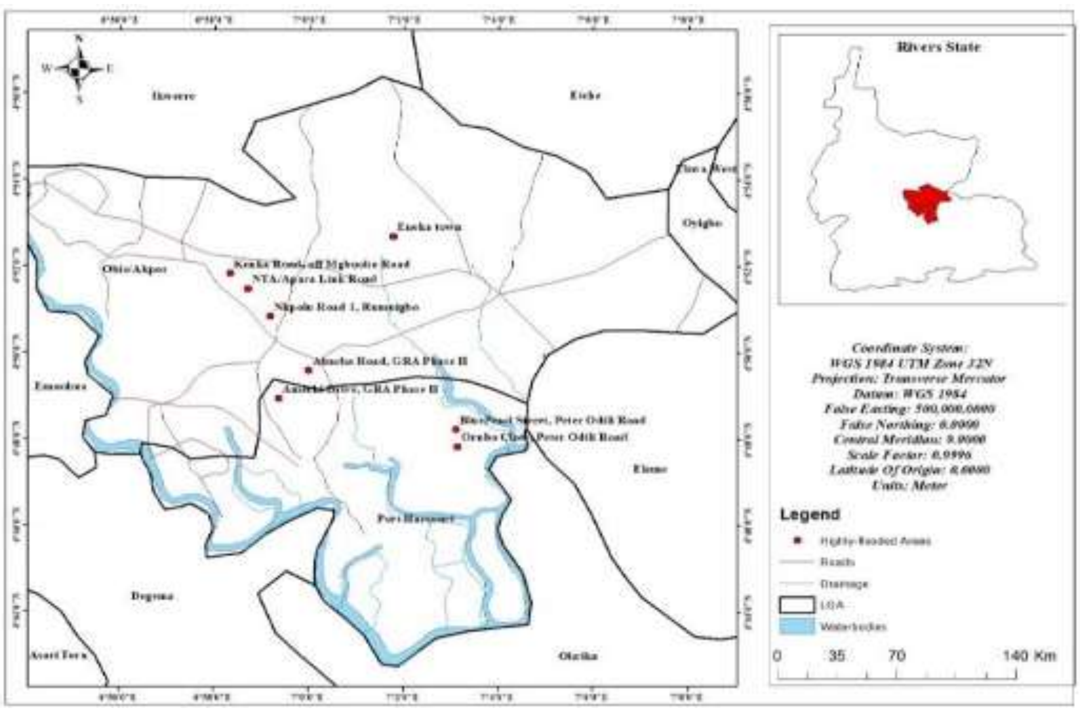

Fig. 8: GPS Map of the Highly Flooded Areas in Port Harcourt Metropolis
(**Source**: Wizor & Mpigi, 2020)

Table 5: Highly Flooded Areas in Port Harcourt Metropolis

S/No	Name of Street / Road	Northings	Eastings
1	Nkpolu Road 1, Rumuigbo	4.853346	6.986527
2	Eneka Town	4.878167	7.029514
3	NTA/Apara Link Road	4.854637	6.983774
4	Rotimi Amaechi Drive, GRA Phase II	4.821278	6.000972
5	Kenka Road, Off Mgbuoba Road	4.856194	6.980361
6	Abacha Road, GRA Phase II	4.823778	7.003361
7	Orubo Close, Peter Odili Road	4.797111	7.052361

8	BluePearl Street, Peter Odili Road	4.794083	7.019917

(**Source:** Wizor & Mpigi, 2020)

Table 6 identifies key highly flooded areas in Port Harcourt Metropolis, each listed with its specific coordinates, indicating their precise locations within the city. Areas such as Nkpolu Road 1 (Rumuigbo), with coordinates (4.853346, 6.986527), and Eneka Town (4.878167, 7.029514) are prone to significant flooding, likely due to rapid urban expansion, poor drainage infrastructure, and the saturation of natural waterways. These locations, positioned within the city's developing neighborhoods, face severe water runoff issues, particularly after heavy rainfall, as the drainage systems in these areas are often inadequate to handle the volume of water. Similarly, streets like NTA/Apara Link Road (4.854637, 6.983774) and Rotimi Amaechi Drive, GRA Phase II (4.821278, 6.000972) also experience flooding, albeit in more established areas. The proximity of these roads to key commercial and residential zones in Port Harcourt suggests that urban development without the necessary flood mitigation measures contributes to the worsening flooding. These highly developed areas have large impermeable surfaces (such as roads and buildings), which do not allow water to seep into the ground, thus contributing to surface runoff and localized flooding. Additionally, Kenka Road, off Mgbuoba Road (4.856194, 6.980361) and Abacha Road, GRA Phase II (4.823778, 7.003361) are situated in low-lying areas, where natural water flow patterns are often disrupted by urbanization. The combination of poor drainage systems and terrain-related challenges makes these areas particularly vulnerable to flooding, especially during the rainy season. Orubo Close, Peter Odili Road (4.797111, 7.052361) and BluePearl Street, Peter Odili Road (4.794083, 7.019917) are also in areas with insufficient water management infrastructure, compounded by the surrounding development, which exacerbates the flooding risk. However, these areas share common challenges such as inadequate drainage, poor urban planning, and rapid urbanization without adequate flood management infrastructure. The geographic coordinates show that these flood-prone areas are spread throughout the city, from residential zones to major roads, highlighting the widespread nature of the flooding problem in Port Harcourt. To mitigate the impacts of flooding, urgent measures such as improved drainage systems, better stormwater management, and sustainable urban planning are necessary to protect these vulnerable areas from future flooding events. In furtherance of this thesis, there was a need to ground-truth the findings of Wizor & Mpigi (2020) to ascertain if the flood situation of the 25 most flooded roads in Port Harcourt Metropolis are still the same. Based on the above, a flood vulnerability map of the 25 most flooded streets/roads in Port Harcourt Metropolis was carried out using ArcGIS (Fig 4.10). Wizor and Mpigi’s 25 most flooded streets/roads of Port Harcourt Metropolis was mapped out using ArcGIS, to find out the vulnerability of the selected flooded areas. The flood vulnerability index of the 25 sampled points in Port Harcourt Metropolis was between -17 and 43. With -17 to 5 being Very High Vulnerable, 5.1 to 11 being High Vulnerable, 12 to 17 being Moderate, 18 to 22 being Low Vulnerable, and 23 to 43 being Very Low Vulnerable. For the sake of this research, the researcher broke it down to 3 groups; highly Vulnerable (-17 to 11), Moderately Vulnerable (12-17), and Lowly Vulnerable (18 to 43).

Flood Vulnerability Table

OBJECTID	Name	Northings	Eastings	RASTERVALU
1	Salem Close, Off Ada George Road	4.85544	6.97956	21
2	Omachi Road, Rumuodomaya	4.87525	6.99978	15
3	Abanna Street, Old GRA	4.78558	7.02203	0
4	Hon. Attah Close, Peter Odili Road	4.79383	7.05075	12
5	Nkpolu Road 1, Rumuigbo	4.85335	6.98653	16
6	Eneka Tow n	4.87817	7.02951	23
7	Horsefall Street, Old GRA	4.78692	7.02122	1
8	Evelyn's Close, GRA Phase 11	4.8195	7.00692	20
9	Omerelu Street, GRA Phase 11	4.83958	7.00564	10
10	Abacha Road, GRA Phase 11	4.82378	7.00336	19
11	Orubo Close, Peter Odili Road	4.79711	7.05236	7
12	NTA/Apara Link Road	4.85464	6.98377	18
13	Obiw ali Road, Rumuigbo	4.85864	6.98694	14
14	L.K. Anga Road, Off Peter Odili Road	4.80192	7.04739	7
15	Uyo Street, Rumumasi	4.83844	7.01758	14
16	Odani Road, Elelenw o	4.84021	7.07351	21
17	Diamond Valley Estate	7.07351	7.04608	9
18	Amaechi Drive, GRA Phase 11	4.82128	6.00097	16
19	BuePearl Street, Peter Odili Road	4.79408	7.01992	0
20	Hilltop Road, Amadi-Kalagbo	4.82381	7.02344	4
21	Kenka Road, Off Mgbuoba Road	4.85619	6.98036	18
22	Akw aka Street, Rumuodomaya	4.88028	6.99428	14
23	Peter Odili Road	4.80486	7.04556	7
24	Alalibo Road, Old GRA	4.79408	7.01992	0
25	Zion Street, Rumuodomaya	4.88161	6.99384	15

Fig. 9: Table of Urban Flood Vulnerability Map of Port Harcourt Metropolis (Source: Researcher, 2024)

Table 6: Comparison of Findings for 25 Most Flooded Streets/Roads in Port Harcourt Metropolis

S/N	Name of Street/ Road	Wizor & Mpigi classification	Flood Vulnerability Map classification	Findings
1	Abanna Street, Old GRA	Lowly flooded	Highly vulnerable	Not in agreement
2	Hon Attah close, Peter Odili Road	Lowly flooded	Moderately vulnerable	Not in agreement
3	L.K. Anga Road, off Peter Odili Road	Lowly flooded	Highly vulnerable	Not in agreement
4	Hiltop Road, Amadi-Kalagbor	Lowly flooded	Highly vulnerable	Not in agreement
5	Uyo Street, Rumuomasi	Lowly flooded	Moderately vulnerable	Not in agreement
6	Omerelu Street, GRA Phase II	Lowly flooded	Highly vulnerable	Not in agreement
7	Akwaka Street, Rumuodomaya	Lowly flooded	Moderately vulnerable	Not in agreement
8	Peter Odili Road	Lowly flooded	Highly vulnerable	Not in agreement
9	Omachi Road, Rumuodomaya	Moderately flooded	Moderately vulnerable	In agreement
10	Salem Close, off Ada George Road	Moderately flooded	Lowly vulnerable	Not in agreement
11	Obi Wali Road, Rumuigbo	Moderately flooded	Moderately vulnerable	In agreement
12	Diamond Valley Estate	Moderately flooded	Highly vulnerable	Not in agreement

Source: (Researcher, 2024)

Table 7: Comparison of Findings for 25 Most Flooded Streets/Roads in Port Harcourt Metropolis (Continued)

S/N	Name of Street/ Road	Wizor & Mpigi classification	Flood Vulnerability Map classification	Findings
13	Zion street, Rumuodomaya	Moderately flooded	Moderately vulnerable	In agreement
14	Odani Road, Elelenwo	Moderately flooded	Lowly vulnerable	Not in agreement
15	Evelyn'S Close, GRA Phase II	Moderately flooded	Lowly vulnerable	Not in agreement
16	Horsefall Street, Old GRA	Moderately flooded	Highly vulnerable	Not in agreement
17	Alalibo Road, Old GRA	Moderately flooded	Highly vulnerable	Not in agreement
18	Nkoplu Road 1, Rumuigbo	Highly flooded	Moderately vulnerable	Not in agreement
19	Rumuewhara New Layout / Eneka Town	Highly flooded	Lowly vulnerable	Not in agreement
20	NTA Apara Link Road	Highly flooded	Lowly vulnerable	Not in agreement
21	Rotimi Amaechi Drive, GRA Phase II	Highly flooded	Moderately vulnerable	Not in agreement
22	Kemka Road, Off Mgbuoba Road	Highly flooded	Lowly vulnerable	Not in agreement
23	Abacha Road, GRA Phase II	Highly flooded	Lowly vulnerable	Not in agreement
24	Orubo Close, Peter Odili Road	Highly flooded	Highly vulnerable	In agreement
25	BluePearl Street, Peter Odili Road	Highly flooded	Highly vulnerable	In agreement

Source: (Researcher, 2024)

The findings from the Flood Vulnerability Map show the vulnerability of the 25 most flooded streets/roads in Port Harcourt Metropolis in comparison with the research conducted by Wizor & Mpigi (2020).

It shows that the lowly flooded streets of Abana Street, Old GRA; L.K. Ang Road, off Peter Odili Road; Hilltop Road, Amadi-Kalagbor; Omerelu Street, GRA Pgase II; and Peter Odili Road are considered highly vulnerable to pluvial flood. While Hon. Attah Close, Peter Odili Road; Uyo Street, Rumuomasi; and Akwaka Street, Rumuodomaya which were classified by Wizor & Mpigi (2020) as lowly flooded are moderately vulnerable. The moderately flooded streets of Diamond Valley Estate; Horsefall Street, Old GRA; and Alalibo Road, Old GRA are considered highly vulnerable. On the other hand, Salem Close, off Ada George Road; Odani Road, Elelenwo; and Evelyn's Close, GRA Phase II are lowly vulnerable. Only 3 streets/roads are in agreement according to the findings. They are Omachi Road, Rumuodomaya; Obi Wali Road, Rumuigbo; and Zion Street, Rumuodomaya. The highly flooded streets/roads of Nkpolu Road 1, Rumuigbo; and Rotimi Amaechi Drive, GRA Phase II are considered as moderately vulnerable. The streets/roads of Rumuewhara New Layout/Eneka Road; NTA/Apara link Road; Kemka Road, off Mgbuoba Road; and Abach Road, GRA PhaseII are considered lowly vulnerable. Only Orubo Close, Peter Odili Road; and BluePearl Street, Peter Odili Road are in agreement with the findings, that they are highly flooded according to Wizor & Mpigi (2020), and highly vulnerable according to the researcher's findings. The flood vulnerability index of the 25 sampled points in Port Harcourt Metropolis was between -17 and 43. With -17 to 5 being Very High Vulnerable, 5.1 to 11 being High Vulnerable, 12 to 17 being Moderate, 18 to 22 being Low Vulnerable, and 23 to 43 being Very Low Vulnerable. For the sake of this research, the researcher broke it down to 3 groups; Highly Vulnerable (-17 to 11), Moderately Vulnerable (12-17), and Lowly Vulnerable (18 to 43).

Flood Vulnerability Table

OBJECTID	Name	Northings	Eastings	RASTERVALU
1	Salem Close, Off Ada George Road	4.85544	6.97956	21
2	Omachi Road, Rumuodomaya	4.87525	6.99978	15
3	Abanna Street, Old GRA	4.78558	7.02203	0
4	Hon. Attah Close, Peter Odili Road	4.79383	7.05075	12
5	Nkpolu Road 1, Rumuigbo	4.85335	6.98653	16
6	Eneka Tow n	4.87817	7.02951	23
7	Horsefall Street, Old GRA	4.78692	7.02122	1
8	Evelyn's Close, GRA Phase 11	4.8195	7.00692	20
9	Omerelu Street, GRA Phase 11	4.83958	7.00564	10
10	Abacha Road, GRA Phase 11	4.82378	7.00336	19
11	Orubo Close, Peter Odili Road	4.79711	7.05236	7
12	NTA/Apara Link Road	4.85464	6.98377	18
13	Obiw ali Road, Rumuigbo	4.85864	6.98694	14
14	L.K. Anga Road, Off Peter Odili Road	4.80192	7.04739	7
15	Uyo Street, Rumumasi	4.83844	7.01758	14
16	Odani Road, Elelenw o	4.84021	7.07351	21
17	Diamond Valley Estate	7.07351	7.04608	9
18	Amaechi Drive, GRA Phase 11	4.82128	6.00097	16
19	BuePearl Street, Peter Odili Road	4.79408	7.01992	0
20	Hilltop Road, Amadi-Kalagbo	4.82381	7.02344	4
21	Kenka Road, Off Mgbuoba Road	4.85619	6.98036	18
22	Akw aka Street, Rumuodomaya	4.88028	6.99428	14
23	Peter Odili Road	4.80486	7.04556	7
24	Alalibo Road, Old GRA	4.79408	7.01992	0
25	Zion Street, Rumuodomaya	4.88161	6.99384	15

Kilometers

Fig. 10: Table of Urban Flood Vulnerability Map of Port Harcourt Metropolis (Source: Researcher, 2024)

Table 8: Comparison of Findings for 25 Most Flooded Streets/Roads in Port Harcourt Metropolis

S/N	Name of Street/ Road	Wizor & Mpigi classification	Flood Vulnerability Map classification	Findings
1	Abanna Street, Old GRA	Lowly flooded	Highly vulnerable	Not in agreement
2	Hon Attah close, Peter Odili Road	Lowly flooded	Moderately vulnerable	Not in agreement
3	L.K. Anga Road, off Peter Odili Road	Lowly flooded	Highly vulnerable	Not in agreement
4	Hiltop Road, Amadi-Kalagbor	Lowly flooded	Highly vulnerable	Not in agreement
5	Uyo Street, Rumuomasi	Lowly flooded	Moderately vulnerable	Not in agreement
6	Omerelu Street, GRA Phase II	Lowly flooded	Highly vulnerable	Not in agreement
7	Akwaka Street, Rumuodomaya	Lowly flooded	Moderately vulnerable	Not in agreement
8	Peter Odili Road	Lowly flooded	Highly vulnerable	Not in agreement
9	Omachi Road, Rumuodomaya	Moderately flooded	Moderately vulnerable	In agreement
10	Salem Close, off Ada George Road	Moderately flooded	Lowly vulnerable	Not in agreement
11	Obi Wali Road, Rumuigbo	Moderately flooded	Moderately vulnerable	In agreement
12	Diamond Valley Estate	Moderately flooded	Highly vulnerable	Not in agreement

Source: (Researcher, 2024)

Table 9: Comparison of Findings for 25 Most Flooded Streets/Roads in Port Harcourt Metropolis (Continued)

S/N	Name of Street/ Road	Wizor & Mpigi classification	Flood Vulnerability Map classification	Findings
13	Zion street, Rumuodomaya	Moderately flooded	Moderately vulnerable	In agreement
14	Odani Road, Elelenwo	Moderately flooded	Lowly vulnerable	Not in agreement
15	Evelyn'S Close, GRA Phase II	Moderately flooded	Lowly vulnerable	Not in agreement
16	Horsefall Street, Old GRA	Moderately flooded	Highly vulnerable	Not in agreement
17	Alalibo Road, Old GRA	Moderately flooded	Highly vulnerable	Not in agreement
18	Nkoplu Road 1, Rumuigbo	Highly flooded	Moderately vulnerable	Not in agreement
19	Rumuewhara New Layout / Eneka Town	Highly flooded	Lowly vulnerable	Not in agreement
20	NTA Apara Link Road	Highly flooded	Lowly vulnerable	Not in agreement
21	Rotimi Amaechi Drive, GRA Phase II	Highly flooded	Moderately vulnerable	Not in agreement
22	Kemka Road, Off Mgbuoba Road	Highly flooded	Lowly vulnerable	Not in agreement
23	Abacha Road, GRA Phase II	Highly flooded	Lowly vulnerable	Not in agreement
24	Orubo Close, Peter Odili Road	Highly flooded	Highly vulnerable	In agreement
25	BluePearl Street, Peter Odili Road	Highly flooded	Highly vulnerable	In agreement

Source: (Researcher, 2024)

The findings from the Flood Vulnerability Map show the vulnerability of the 25 most flooded streets/roads in Port Harcourt Metropolis in comparison with the research conducted by Wizor & Mpigi (2020). It shows that the lowly flooded streets of Abana Street, Old GRA; L.K. Ang Road, off Peter Odili Road; Hilltop Road, Amadi-Kalagbor; Omerelu Street, GRA Pgase II; and Peter Odili Road are considered highly vulnerable to pluvial flood. While Hon. Attah Close, Peter Odili Road; Uyo Street, Rumuomasi; and Akwaka Street, Rumuodomaya which were classified by Wizor & Mpigi (2020) as lowly flooded are moderately vulnerable.

The moderately flooded streets of Diamond Valley Estate; Horsefall Street, Old GRA; and Alalibo Road, Old GRA are considered highly vulnerable. On the other hand, Salem Close, off Ada George Road; Odani Road, Elelenwo; and Evelyn's Close, GRA Phase II are lowly vulnerable. Only 3 streets/roads are in agreement according to the findings. They are Omachi Road, Rumuodomaya; Obi Wali Road, Rumuigbo; and Zion Street, Rumuodomaya. The highly flooded streets/roads of Nkpolu Road 1, Rumuigbo; and Rotimi Amaechi Drive, GRA Phase II are considered as moderately vulnerable. The streets/roads of Rumuewhara New Layout/Eneka Road; NTA/Apara link Road; Kemka Road, off Mgbuoba Road; and Abach Road, GRA PhaseII are considered lowly vulnerable. Only Orubo Close, Peter Odili Road; and BluePearl Street, Peter Odili Road are in agreement with the findings, that they are highly flooded according to Wizor & Mpigi (2020), and highly vulnerable according to the researcher's findings.

The respondent's perceptions of the magnitude and severity of pluvial flooding in their neighborhoods, a significant portion of respondents, 52.7%, rated the magnitude of flooding as "Moderate - Above Ankle (101mm to 200mm)," suggesting that while flooding is disruptive, it is not excessively severe in most cases. This moderate level of flooding may result from insufficient drainage systems and partially blocked water channels. Additionally, 33.6% of respondents categorized flooding as "High - Above Knee (201mm to 600mm)," indicating a more severe disruption in these areas. A smaller proportion, 12.5%, rated flooding as "Low – Ankle (51mm to 100mm)," reflecting relatively minor impacts, likely in areas with better drainage infrastructure or higher elevation. Notably, only 1.2% reported "Severe - Waist Level (601mm to 900mm)" flooding, suggesting that extreme flooding events are less frequent but highly impactful when they occur. These results underscore the variability in flood magnitude across neighborhoods and highlight the need for tailored interventions to address both moderate and severe flood risks effectively. The distribution of flood durations across the study areas, the majority of respondents, 30.3%, indicated that flood durations typically exceed 30 minutes, marking it as the most common flood duration in the area. A significant portion of respondents reported flood durations ranging from one hour (16.8%) to two hours (19.7%), while a smaller group (1.8%) mentioned floods lasting up to five hours. In total, about 38.3% of respondents experienced flooding that lasted between one and five hours after a heavy downpour. These Results highlight the prolonged nature of flooding in the area, emphasizing the need for improved drainage systems and flood control measures to address this persistent issue.

Discussion of Findings

The objective of the study was to identify the areas within Port Harcourt Metropolis that are most vulnerable to perennial pluvial flooding. However, 13 streets/roads were chosen from the 25 most flooded areas in Port Harcourt Metropolis; 4 lowly flooded, 5 moderately flooded, and 4 highly flooded. The 4 lowly flooded areas in Port Harcourt Metropolis, include Abanna Street (Old GRA), Hon. Attah Close, Uyo Street, and Akwaka Street. These areas, located within latitudes 4.78°–4.88° and longitudes 6.99°–7.05°, have altering elevations (ranging from 3.6m to 14.1m above sea level), better drainage infrastructure, and efficient urban planning. Even though they were classified as being lowly flooded by Wizor & Mpigi (2020), the flood vulnerability map grouped them as being highly vulnerable (Abanna street), and moderately vulnerable (Hon. Attah close, Akwaka street, and Uyo street). The findings reveal that these could be as a result of causational factors caused by human and climatic variables.

Findings on identified moderately flooded areas within Port Harcourt Metropolis, identified five moderately flooded areas in Port Harcourt Metropolis, including locations like Rumuodomaya, Ada George Road, Rumuigbo, Elelenwo, and GRA Phase II, within latitudes 4.81°–4.87° and longitudes 6.97°–7.07°. Flooding in these areas, such as Omachi Road in Rumuodomaya, Salem Close off Ada George road, Obi Wali Road in Rumuigbo, Odani road at Elelenwo, and Evelyn's close at GRA Phase II, is attributed to urban development and poor drainage. The findings stress the need for improved drainage, urban planning, and water retention systems.

Findings on highly flooded areas in Port Harcourt metropolis, identifies four highly flooded areas in Port Harcourt Metropolis, including Nkpolu Road 1 (Rumuigbo), Rumuewhara New Layout/Eneka Town, NTA/Apara Link Road, and Abacha road. These locations are prone to severe flooding due to rapid urbanization, inadequate drainage, and poor stormwater management. The areas, which span both developing and established neighborhoods, suffer from surface runoff caused by large impermeable surfaces like asphalt roads, and "increte" stamped concrete pavers in residential compounds. The widespread nature of flooding in these areas emphasizes the need for improved drainage systems, sustainable urban planning, and better water management strategies.

Findings on identifies flooded areas within Port Harcourt Metropolis using field observation by the researcher, highlights varying flood classifications and elevations across Port Harcourt Metropolis. Highly flooded areas include Rumuewhara New Layout/Eneka (17.1m elevation), NTA/Apara Link Road (13.5m), Abacha Road, GRA Phase II (4.2m), and Nkpolu Road 1, Rumuigbo (14.1m), with floodwaters reaching up to 200mm in some areas. Moderately flooded locations, such as Salem Close and Obiwali Road, showed lesser impacts, while low flooding was observed in areas like Abanna Street and Akwaka Street. Flood management relies on community-driven measures, including flood barriers and raised driveways, as no government adaptation strategies were physically evident, emphasizing the need for comprehensive intervention.

Findings on Percentage Distribution of Mostly Flooded Parts of Port Harcourt Metropolis reveals that over 90% of respondents consider Obio/Akpor Local Government Area the most flooded part of Port Harcourt Metropolis, indicating its high vulnerability to severe flooding, factors such as poor drainage, rapid urbanization, low elevation, and impermeable surfaces likely contribute to this issue. On the other hand, 10% of respondents identified Port Harcourt City Local Government Area as the most flooded, pointing to localized flooding challenges within specific parts of the city. These results highlight the importance of implementing focused flood management solutions in both areas to address their distinct needs (Figure 4.10). Findings on perceptions of pluvial flood magnitudes in identified neighborhoods, shows that the majority (52.7%) rated flooding as "Moderate - Above Ankle (101mm to 200mm)," indicating frequent but manageable flooding. A significant portion (33.6%) experienced "High - Above Knee (201mm to 600mm)" flooding, suggesting more severe disruptions. Only 12.5% reported "Low – Ankle (51mm to 100mm)" flooding, reflecting areas with less impact, possibly due to better drainage or higher elevation. A minimal 1.2% described the flooding as "Severe - Waist Level (601mm to 900mm)," highlighting rare but extreme flooding events. These results emphasize the varying flood impacts across neighborhoods and the need for tailored flood management strategies.
Findings on flood durations across the study areas reveals that majority of respondents (30.3%) reported floods lasting over 30 minutes, making it the most common flood duration. A significant portion of respondents experienced flooding for one hour (16.8%) and two hours (19.7%). A smaller group (1.8%) reported floods lasting up to five hours. Cumulatively, 38.3% of respondents experienced flooding lasting between one and five hours after a downpour. These results underscore the prolonged nature of flooding in the area, highlighting the urgent need for improved flood management and drainage systems.

Conclusion

The study identified key areas within Port Harcourt Metropolis most vulnerable to perennial pluvial flooding. Using field observations, the research highlighted flood-prone locations such as Rumuewhara New Layout/Eneka (17.1m elevation), NTA/Apara Link Road (13.5m), and Abacha Road, GRA Phase II (4.2m), where floodwaters reached up to 200mm. moderately affected areas like Salem Close experienced lesser impacts, while minimal flooding was observed in Abanna Street. Findings indicate that over 90% of respondents identified Obio/Akpor Local Government Area as the most severely affected due to poor drainage, rapid urbanization, and low elevation. Perceptions of flood magnitudes revealed that most respondents (52.7%) experienced "Moderate" flooding, while 33.6% faced "High" flooding, with a minority reporting severe events. Flood durations commonly exceeded 30 minutes, with cumulative 38.3% experiencing floods lasting one to five hours, underscoring the prolonged nature of flooding in the area. The findings revealed that most residents experience moderate to high flood magnitudes, with events lasting several hours, emphasizing the recurrent and disruptive nature of flooding in the area. Impacts on infrastructure were substantial, with severe health risks from contaminated water, extensive property damage, and a decline in architectural quality. Water stains, structural corrosion, and diminished aesthetic appeal were commonly reported, alongside moderate discomfort in affected buildings. Despite satisfactory ratings for building durability, concerns over aging materials and poor maintenance highlight the need for more resilient architectural designs

Recommendations

- **i.** There is need for the development of a comprehensive Flood Resilient Design Framework (FRDF) is crucial, integrating architectural adaptation strategies, stakeholder engagement, and policy recommendations. This framework will enhance the city's resilience against future flood events, improving the quality of life for its residents.
- ii. A sustainable drainage system aims to mimic as closely as possible the natural drainage of an urban area to minimize the impact of urban development on the flooding and pollution of waterways. These may take the form of areas of vegetation such as grassy banks or green roofs, or natural water reduces the probability of damage. This type of risk prevention is of great importance for areas with great flood depth.
- iii. Low-cost houses in less flood-prone areas in Port Harcourt metropolis should be built by the government where affected residents or evacuated victims especially from the flood vulnerability “hotspots” could stay temporarily during flood peak periods till dry season.
- **iv.** National Emergency Management Agency (NEMA) should equally be equipped to evacuate victims during flood emergencies as well as distribute relief materials to relieve victims of sustained shocks. Observations and interviews show that NEMA had demonstrated a poor capability in managing flood disasters in Port Harcourt metropolis. Although, NEMA is a Federal parastatal, the Government of Rivers State can give subvention to this agency to help in times of flood emergencies.

REFERENCES

Adelekan, I. O. (2010). Vulnerability assessment of an urban flood in Nigeria: Abeokuta flood 2007. *Natural Hazards, 56, 215-231.*

Adeloye, A., & Rustum, R. (2011). Lagos (Nigeria) flooding and influence of urban planning. *Journal of Urban Design and Planning, 164, 175-187.*

Adger, W. N. (2006). Vulnerability. Global Environmental Change, 16, 268-281. Ali, A. M. S. (2007). September 2004 flood event in South Western Bangladesh: A study of its nature, causes, and human perception and adjustments to a new hazard. Natural Hazards, 40, 89-111.

Allen, K. (2003). Vulnerability reduction and the community-based approach. In M. Pelling (Ed.), Natural disasters and development in a globalising world (pp. 170-184). London, England: Routledge.

Amakiri, I. T., Nkeiruka, O. A., & Okey-Ejiowhor, C. H., (2022). Housing challenge and urban infrastructure development in Rivers State. *International Journal of Innovative Environmental Studies Research 9(2):9-15,*

Aragon-Durand, F. (2007). Urbanization and flood vulnerability in the peri-urban interface of Mexico City. *Disasters, 31, 477-494.*

Ayoade, J. O. (1979). A note on the recent flood in Ibadan. *Savanna, 8(1), 62-65.*

Ayoade, J. O., & Akintola, F. O. (1980). Public perception of flood hazard in two Nigerian cities. *Environment International, 4, 277-280.*

Bankoff, G. (2003). Constructing vulnerability: The historical, natural and social generation of flooding in metropolitan Manila. *Disasters, 27, 224-238.*

Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework (Tyndall Centre Working Paper No. 38). University of East Anglia, Norwich, UK.

Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change, 15, 151-163.*

Dimkpa, K., Ohochuku, P. C., Adibe, O. N., & Okey-Ejiowhor, H. C. (2024). Architectural Resilience: Navigating Climatic Challenges in Secondary School Buildings across Port Harcourt Local Government Area, Rivers State. *Journal of Engineering, Mechanics and Modern Architecture, 3(4), 23-33.*

Dutta, D., Khatun, F., & Herath, S. (2005). Analysis of flood vulnerability of urban buildings and populations in Hanoi, Vietnam. *Seisan Kenkyu, 57, 338-342.*

Falconer, R. A., Smith, M., & Jones, T. (2022). *Impacts of high-intensity rainfall on urban flooding: Comparative analysis of pluvial and flash flooding*. *Journal of Hydrology, 598, 125723. https://doi.org/10.1016/j.jhydrol.2022.125723*

Fussel, H. M., & Klein, R. J. T. (2006). Climate change vulnerability assessment: An evolution of conceptual thinking. *Climate Change, 75, 301-329.*

Gbetibouo, G. A., & Ringler, C. (2009). Mapping South African farming sector vulnerability to climate change and variability: A sub-national assessment (IFPRI Discussion Paper 00885). Washington, DC: International Food Policy Research Institute, Environment and Production Technology Division.

Heltberg, R., & Bonch-Osmolovskiy, M. (2011). Mapping vulnerability to climate change (Policy Research Working Paper No. 5554). Washington, DC: The World Bank, Sustainable Development network, Social Development Unit.

Hinkel, J. (2011). Indicators of vulnerability and adaptive Capacity: Towards a clarification of the Science-policy interface. *Global Environmental Change, 21, 198-208.*

Ishaya, S., Ifatimehin, O. O., & Abaje, I. B. (2009). Mapping flood vulnerable areas in a developing urban centre of Nigeria. *Journal of Sustainable Development in Africa, 11, 180-194.*

Kenny, M., Booth, M., & Austin, L. (2021). *Impact of Urbanization and Land Use on Flooding in the Niger Delta Region of Nigeria*. *Journal of Flood Risk Management, 14(2), 101-112.*

Kundzewicz, Z., Hoozemans, F., & Svensson, J. (2022). *Pluvial Floods and Climate Change: Impacts and Adaptation Strategies*. *Climate Change and Urban Flooding, 48(6), 423-435.*

Lennon, M. (2015). Green infrastructure and planning policy: The resilience of the English spatial planning system. *Journal of Environmental Planning and Management*, *58*(8), 1391-1408.

Li, Z., Liu, W., & Zhang, J. (2019). Sponge city construction in China: A review. *Journal of Cleaner Production, 235, 131-143.*

Liu, Y., Li, Y., & Qin, H. (2014). Blue-Green Infrastructure: Effective measures for urban flood risk management. *Water Management*, *8*(3), 197-209.

Maddox, A., Dixon, S. H., & Foster, C. E. (2020). Coastal and riverine flooding: Causes, effects, and mitigation strategies. *Journal of Climate Adaptation*, *15*(1), 32–45.

Malone, E. L., & Engle, N. L. (2011). Evaluating regional vulnerability to climate change: Purposes and methods. Wiley Interdisciplinary Reviews: *Climate Change, 2, 462-474. doi:10.1002/wcc.116*

Metzger, M. J., & Schroter, D. (2006). Towards a spatially explicit and quantitative vulnerability assessment of environmental change in Europe. *Regional Environmental Change, 6, 201-216.*

Midgley, S. J. E., Davies, R. A. G., & Chesterman, S. (2011, November). Climate risk and vulnerability mapping: Status quo (2008) and future (2050). Paper presented at the Regional Climate Change Programme Southern Africa (RCCP), UK Department for International Development (DFID), OneWorld sustainable Investments, Cape Town, South Africa.

Mukhopadhyay, S. (2010). A geo-environmental assessment of flood dynamics in lower Ajoy River inducing sand splay problem in Eastern India. *Ethiopian Journal of Environmental Studies and Management*, *3(2), 1-15.*

Nicholls, R. J., Hoozemans, F. M. J., & Marchand, M. (1999). Increasing flood risk and wetland losses due to global sea-level rise: Regional and global analyses. *Global Environmental Change*, *9, S69-S87.*

Núñez, M., Fernandez, T., & Gómez, L. (2021). *Urban Drainage and Flooding: New Approaches in Stormwater Management*. Environmental Science & Policy, 123, 56-64.

Ogba, C. O., & Utang, B. P. (2008). Integrated approach to urban flood adaptation in the Niger Delta Coast of Nigeria. integrating generations. Stockholm, Sweden: FIG Working Week.

Ogu, V., & Adekola, A. (2022). *Flood Management and the Role of Local Governments in Nigeria*. *Journal of Environmental Policy and Administration, 25(1), 77-85.*

Okey- Ejiowhor, C. H., Amakiri, I. T., & Nkeiruka, O. A. (2022). The impact of rural urban migration on housing deficit in Port Harcourt Local Government Rivers State. *International Journal of Innovative Human Ecology & Nature Studies 10(2):1-8,*

Oku, H. B., Wichendu, S., & Poronaike, B. N. (2011). Adjustment strategies to flood hazards in Port Harcourt, Nigeria. *Nigerian Journal of Agriculture*, *Food and Environment*, *7(4):1-4.*

Ologunorisa, T. E. (2004). An assessment of flood vulnerability zones in the Niger Delta, Nigeria. *International Journal of Environmental Studies, 61, 31-38.*

Ologunorisa, T. E., & Abawua, M. J. (2005). Flood risk assessment: A review. *Journal of Applied Sciences & Environmental Management, 9(1), 57-63.*

Ologunorisa, T. E., & Terso, T. (2006). The changing rainfall pattern and its implications for flood frequency in Makurdi, Northern Nigeria. *Journal of Applied Sciences & Environ Management, 10(3), 97-102.*

Olorunfemi, F. B. (2011, May 3). Managing flood disasters under a changing climate: Lessons from Nigeria and South Africa (NISER Discussion Paper No. 1). Paper presented at NISER Research Seminar Series, NISER, Ibadan.

Piroozfar, P., Sarlak, M., & Erdem, E. (2020). *Sustainable Urban Drainage Systems for Flood Mitigation in Urban Areas: A Review*. Urban Sustainability, 8(2), 156-173.

Sallis, J. F., Cerin, E., Conway, T. L., Adams, M. A., Frank, L. D., Pratt, M., ... & Davey, R. (2016). Physical activity in relation to urban environments in space and time: A systematic review of empirical studies. Social Science & Medicine, 147, 45-53.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity, and vulnerability. *Global Environmental Change, 16, 282-293.*

Stoltman, J. P., Lidstone, J., & Dechano, L. M. (2004). International perspectives on natural disasters: Occurrence, mitigation, and consequences. New York, NY: Springer.

Thieken, A. H., Kreibich, H. M. M., & Merz, B. (2007). Coping with floods; preparedness, response and recovery of flood affected residents in Germany in 2002. *Hydrological Sciences Journal, 52, 1016-1037.*

Thorton, P. K., Jones, P. G., Owiyo, T., Kruska, R. L., Herrero, M., Kristjanson, P., Omolo, A. (2006). Mapping climate vulnerability and poverty in Africa (Report to the Department for International Development). Nairobi, Kenya: The International Livestock Research Institute.

Vincent, K. (2004). Creating an index of social vulnerability to climate change for Africa (Working Paper No. 56). Norwich, UK: Tyndall Center for Climate Change Research.

Ward, R. C. (1978). Floods: A geographical perspective. London, England: The Macmillan Press.

World Bank (2023). *Urban Flooding and Climate Change: Challenges in Sub-Saharan Africa*. Climate Change and Development, 31(1), 45-60.

Yusuf, A. A., & Francisco, H. A. (2009, November). Climate change vulnerability mapping for South-East Asia. Report for Akukwe and Ogbodo 19 the IDRC, Economy and Environment Program for South-East Asia, Swedish International Development Cooperation Agency, Canadian International Development Agency, Singapore.

Zabbey, N. (2006). Flood hazard vulnerabilities and coping strategies of residents of urban settlements in Metro Manila, the Philippines. In D. J. Parker (Ed.), Floods (pp. 69-88). London, England: Routledge. Author Biographies