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Assessment of Climate Change Impact on Housing Quality in Port Harcourt, Rivers State, Nigeria

Olutope Adeniyi Adewole[1]; Ayokunle A. Akinmoladun[2]; Wemomo Leyetunde Omoniyi[3]

[1,2,3] Caleb University
University in Nigeria

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Abstract: This systematic review assesses the impact of climate change on housing quality in Port Harcourt, Nigeria, by synthesizing evidence from 22 studies. The objective was to disaggregate housing into specific quality dimensions—structural integrity, material durability, thermal comfort, moisture control, sanitation functionality, and habitability—to precisely identify damage pathways and evaluate adaptation effectiveness. Employing a systematic literature review methodology, the study analyzed peer-reviewed and grey literature. Findings reveal a multi-hazard environment where intensifying flooding, extreme urban heat (with Land Surface Temperature increases up to 8°C), and sea-level rise systematically degrade all housing dimensions. These impacts are critically mediated by socio-economic inequality, tenure insecurity, and institutional failures, concentrating vulnerability in informal settlements. Current adaptation is predominantly reactive and maladaptive, with policy implementation gaps undermining resilience. The study concludes that effective adaptation requires integrated interventions that simultaneously address physical hazards and the underlying socio-economic drivers of vulnerability, advocating for targeted retrofitting programs, tenure-secure upgrading, and nature-based infrastructure to enhance housing resilience in coastal African cities.

***Keywords**: Climate Change, Climate Risk, Housing Quality, Urbanization, Port Harcourt.*

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I. INTRODUCTION

Port Harcourt, with a metropolitan population of about 3.7 million and growing at nearly 5% annually, has far outstripped its infrastructure and planning capacity (Macrotrends, 2025). This has led to widespread informal settlements in high-risk floodplains and a critical deficit in protective services like drainage and waste management, establishing a precarious foundation for climate resilience in the housing sector (Echendu, 2025).

The impacts of climate change on urban systems are often discussed at aggregate levels, but their most visceral and damaging manifestations occur at the scale of the individual home (Anggraeni et al., 2015). In Port Harcourt, the degradation of housing quality is critical, yet underexplored. While national climate policies frequently focus on macroeconomic indicators or agricultural impacts, they often obscure the building-level processes through which hazards degrade urban habitability (Owotemu, Yakubu & Onuoha, 2025).

The disconnect between national narratives and local realities becomes starkly evident in flood risk assessment, where hyperlocal factors like micro-topography, settlement patterns, and housing materials mediate vulnerability in ways that aggregate national studies miss (David et al., 2023). International literature provides robust evidence of climate-housing interactions, documenting material corrosion from saltwater intrusion, foundation instability, and health impacts from damp housing in diverse contexts (Bates, 2010; Dhara, Schramm & Luber, 2013). In contrast, local literature for Port Harcourt remains fragmented, often clustering around documentation of flood events or broad vulnerability assessments, with critical gaps in understanding how specific hazards degrade specific housing quality dimensions over time (Aliyu & Amadu, 2017; Okey-Ejiowhor & Akani, 2025).

Therefore, this research seeks to provide a systematic assessment of how climate change impacts housing quality in Port Harcourt by disaggregating housing into measurable quality dimensions, evaluating hazard interactions, and identifying effective adaptation pathways. This aim will be pursued through the following interconnected research questions:

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- Which climate hazards affecting Port Harcourt are documented in the literature and how are their characteristics changing?
- How do these hazards affect specific housing quality dimensions—structural integrity, material durability, thermal comfort, moisture control, sanitation functionality, and habitability?
- What socio-economic, institutional, and tenure factors mediate these impacts across different housing typologies and neighborhoods?
- What adaptation, retrofitting, or policy measures are reported in the Port Harcourt context and how effective are they in preserving housing quality?
- What measurement and methodological gaps persist in assessing climate-housing interactions in this context?

This paper's novelty lies in its city level synthesis that deliberately disaggregates housing quality into constituent dimensions, enabling precise identification of damage pathways and intervention points. By moving beyond generic vulnerability assessments to examine specific material, structural, and functional interactions between climate and housing, the research aims to inform more targeted adaptation planning for coastal cities facing similar challenges.

II. LITERATURE REVIEW

➢ *Geographical and Socio-Economic Context of Port Harcourt*

Port Harcourt, the capital of Rivers State in southern Nigeria, occupies a strategic yet vulnerable position within the Niger Delta region, situated along the Bonny River approximately 41 miles upstream from the Gulf of Guinea (Igwe, 2019). Founded in 1912 as a colonial port for coal exports, the city has evolved into Nigeria's fifth largest urban agglomeration, with a metropolitan population approaching 3.7 million people (Igwe, 2019; Echendu, 2025; Macrotrends, 2025). Its coastal riverine setting fundamentally shapes both its economic significance and environmental vulnerability, creating a complex interface between urban development and natural systems. Port Harcourt also serves as the epicenter of Nigeria's petroleum industry, hosting major international oil companies including Shell and Chevron, and exporting the country's first shipment of crude oil in 1958 (Oguntoye & Oguntoye, 2021). This economic dominance has accelerated urbanization while simultaneously introducing environmental stressors that compound climate vulnerability (Tari, Brown & Chikagbum, 2015; Dan-Jumbo, 2018; Greenwalt et al., 2021).

In addition, the city's geographical characteristics render it inherently susceptible to climate impacts. Located at coordinates 4°49′27″N and 7°2′1″E, Port Harcourt features a tropical monsoon climate (Köppen: Am) characterized by lengthy, intense rainy seasons and brief dry periods (Weather Atlas, n.d.). With annual precipitation exceeding 3,000mm and the heaviest rainfall occurring in September (averaging 367mm), the city's low lying topography and extensive water networks create natural flood pathways that increasingly threaten urban settlements (Weather Atlas, n.d.; Echendu, 2021). The convergence of economic assets and environmental exposure establishes Port Harcourt as a critical location for examining climate-housing interactions in coastal African cities (Tari, Brown & Chikagbum, 2015; Greenwalt et al., 2021). Especially with the current challenges of rapid, unplanned urbanization.

➢ *Urbanization Pressures and Infrastructure Deficits*

Port Harcourt has experienced explosive demographic growth, expanding from just 59,752 inhabitants in 1950 to an estimated 3,794,000 urban residents in 2025—representing nearly sixty fold growth in seven decades (Macrotrends, 2025). Current estimates indicate the metropolitan area grows at approximately 4.99% annually, one of the highest rates in West Africa (Macrotrends, 2025). According to Echendu (2025), this growth is primarily driven by natural increase rather than migration, with a youthful population base that ensures continued expansion regardless of migration patterns. Such rapid demographic change has been noted to have profoundly strained the city's capacity for planned development and infrastructure provision (Montgomery et al., 2013; Pandey & Ghosh, 2023; Duminy et al., 2023).

This urbanization process in Port Harcourt exhibits what urban scholars term "urbanization without industrialization," where demographic growth outstrips economic formalization and infrastructure investment (Gollin, Jedwab & Vollrath, 2016; Aliyu & Amadu, 2017; Gross & Ouyang, 2021). The critical infrastructure deficits permeate multiple sectors, with over 70% of Nigeria's road network classified as 'in poor condition,' power shortages being chronic, and only 30% of the country's infrastructure stock meeting GDP benchmarks (Ogundeji, 2025). Due to this, the African Development Bank estimates Nigeria requires approximately $100 billion annually to bridge its infrastructure gap (Ogundeji, 2025). In Port Harcourt specifically, these infrastructure deficits manifest through inadequate drainage systems, an unreliable water supply, and insufficient waste management—all critical determinants of housing resilience to climate impacts (Okey-Ejiowhor & Akani, 2025).

According to Echendu (2025), Housing development has largely occurred through informal mechanisms, with only 20-40% of urban physical development receiving formal government approval; and the proliferation of informal settlements, particularly in low lying floodplain areas, has created urban landscapes where vulnerable populations concentrate in high risk zones without adequate protective infrastructure. The 2009 establishment of the Greater Port Harcourt region—spanning eight local government areas—represented a policy recognition of the need to decongest the urban core, yet implementation challenges persist (Simeipiri & Ikiriko, 2022). This urban expansion occurs within a context of inadequate maintenance culture, with approximately 60% of existing infrastructure assets neglected or poorly maintained according to engineering assessments (Ogundeji, 2025). The convergence of rapid urbanization, infrastructure deficits, and informal settlement patterns establishes a precarious foundation for climate resilience in the housing sector.

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➢ *Climate Risk Narratives: National Aggregates Versus Local Realities*

National climate policy frameworks in Nigeria frequently prioritize aggregate metrics and macroeconomic impacts, obscuring the highly localized processes through which climate hazards affect housing quality (Owotemu, Yakubu & Onuoha, 2025; Mbalisi, Mbalisi & Nwaiwu, 2025). National assessments typically emphasize agricultural productivity, energy security, and broad economic indicators, while paying insufficient attention to the building scale mechanisms through which climate change degrades urban habitability (Aliyu & Amadu, 2017; Owotemu, Yakubu & Onuoha, 2025). This analytical gap is particularly problematic for coastal cities like Port Harcourt, where global climate trends interact with local environmental conditions to produce unique vulnerability profiles.

The disconnect between national narratives and local realities becomes evident in flood risk assessment. While national policies might emphasize river basin management and regional precipitation trends, Port Harcourt's flood vulnerability is mediated through hyperlocal factors including micro-topography, settlement patterns, drainage maintenance, and housing materials (David et al., 2023; Ogboeli, Chilaka & Dan, 2024). The city's position within the Niger Delta creates a multi hazard environment where coastal flooding, riverine overflow, and pluvial flooding converge, yet national risk assessments rarely capture these intersecting dynamics at the neighborhood scale (David et al., 2023). Furthermore, the temporal dimension of risk is often misrepresented in national frameworks, which tend to focus on extreme events while overlooking the cumulative degradation caused by recurrent, small scale flooding and persistent humidity (Okey-Ejiowhor & Akani, 2025).

The socio-economic mediation of climate impacts further complicates the national-local risk assessment disconnect. While national data might indicate Port Harcourt's economic significance through its GDP contribution (approximately $34.4 billion PPP), these aggregates mask stark inequalities in climate vulnerability (Greenwalt et al., 2021; Tellusant, 2024). The city's population includes significant numbers of urban poor concentrated in flood prone informal settlements like Diobu, Oroworukwo, and Nkpogu—areas originally absorbed during the city's expansion (Greenwalt et al., 2021). For these residents, climate impacts on housing represent not merely property damage but fundamental threats to health, livelihoods, and household stability. A critical reassessment of climate risk frameworks is therefore necessary to bridge the scale gap between national policy and local housing realities.

➢ *International Evidence and Local Knowledge Gaps*

The international literature provides robust evidence of the pathways through which climate change affects housing quality. Multiple studies across diverse geographical contexts have documented material degradation mechanisms, including accelerated weathering of building materials from increased precipitation, foundation instability from soil moisture fluctuations, and corrosion from saltwater intrusion in coastal areas (Bates, 2010; Rincon et al., 2024; Norman et al., 2024; Xu, 2025). The thermal dimension of climate change has similarly been shown to affect housing quality through indoor temperature extremes that compromise thermal comfort, particularly in structures with inadequate ventilation or thermal insulation, in studies like those by Barbosa, Vicente & Santos (2015), Santamouris & Kolokotsa (2015), Ozarisoy & Elsharkawy (2019), Emmitt (2023), and Hampo, Schinasi & Hoque (2024). These physical processes are well established in building science research, particularly in temperate and Asian contexts (Anggraeni et al., 2015; Xu, 2025).

In the global South, research has increasingly documented the compound nature of climate-housing interactions, where physical damage to structures intersects with public health concerns. Studies in flood prone informal settlements from Mumbai to Lagos have identified moisture related mold proliferation as a trigger for respiratory illnesses, while stagnant water creates breeding grounds for vector borne diseases (Dhara, Schramm & Luber, 2013; Aliyu & Amadu, 2017; Chikezie et al., 2024). The literature also highlights adaptive building technologies, ranging from elevated foundations in Bangladesh (Khan, 2024) to moisture resistant materials in Vietnam (Lee & Le, 2024), demonstrating context specific solutions to climate-housing challenges.

➢ *Research Gaps*

Despite this international evidence, research specific to Port Harcourt and the Niger Delta remains fragmentary. The limited local literature clusters around several themes of documentation of flood extent and frequency (Dan-Jumbo, 2018; Okey-Ejiowhor & Akani, 2025), broad assessments of urban infrastructure deficits (Echendu, 2021), and general climate vulnerability analyses (Aliyu & Amadu, 2017; Ogundeji, 2025). However, critical gaps persist in understanding the building level processes through which specific climate hazards degrade specific housing quality dimensions. Few studies examine how recurrent flooding compromises structural integrity in different housing typologies or how increasing humidity interacts with ventilation standards to affect indoor air quality. The effectiveness of autonomous adaptation measures employed by residents remains largely unassessed, while regulatory frameworks for climate-resilient housing remain unexplored. This knowledge fragmentation impedes the development of targeted interventions to enhance housing resilience in Port Harcourt.

➢ *Theoretical Framework*

This research adopts the IPCC risk framework conceptualizing climate risk as the interaction of hazards, exposure, and vulnerability (IPCC, 2022). This theoretical approach enables a systematic examination of how climate hazards (e.g., flooding, sea level rise, temperature extremes) interact with the exposure of housing stocks and their inherent vulnerability (determined by construction quality, maintenance, and socio-economic factors). The framework emphasizes that climate impacts on housing are not determined by hazard characteristics alone, but through

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the mediating influence of physical and social vulnerability factors (Few, 2007; Sharma & Ravindranath, 2019). This conceptualization helps transcend deterministic hazard-centric approaches that dominate popular discourse on climate impacts.

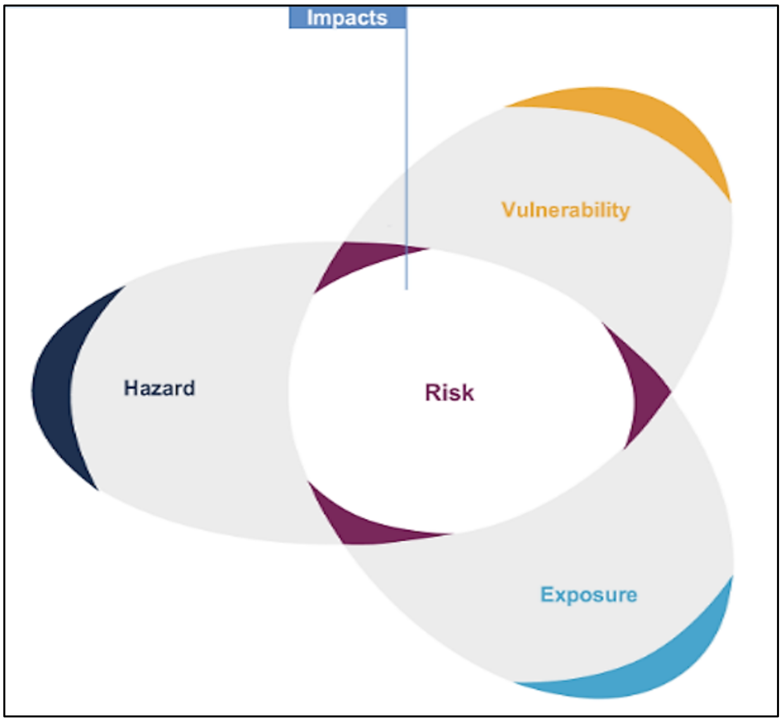

Fig 1: IPCC Risk Framework (IPCC, 2022)

The policy relevance of this approach lies in its ability to identify intervention points across multiple risk dimensions. Rather than focusing exclusively on hazard mitigation (e.g., through drainage improvements), the framework encourages simultaneous attention to reducing exposure (through zoning and settlement patterns) and vulnerability (through building codes, retrofitting programs, and poverty reduction) (Sharma & Ravindranath, 2019; Monteiro et al., 2022). This multidimensional approach aligns with the Sustainable Development Goals, particularly Goal 11 targeting inclusive, safe, resilient, and sustainable cities. The public health imperative for this research emerges from the well established linkages between housing conditions and health outcomes—connections that climate impacts potentially worsen through multiple pathways including water contamination, mold proliferation, and thermal stress.

III. METHODOLOGY

This study employed a systematic literature review methodology to comprehensively assess and integrate existing evidence on climate change impacts on housing quality in Port Harcourt, Nigeria. This approach was selected for its capacity to rigorously identify, evaluate, and synthesize findings from a fragmented and multidisciplinary body of literature, thereby providing a robust evidence base and clearly identifying knowledge gaps (Bradbury-Jones et al., 2019). The methodology was designed to directly address the five research questions by systematically extracting and analyzing data from published and grey literature.

➢ *Research Design*

The research design followed a two stage sequential process; first, a systematic mapping of the evidence base, followed by a thematic synthesis. This design is recommended for complex, interdisciplinary topics where the literature is diverse in scope and methodology (Thomas & Harden, 2008; Bradbury-Jones et al., 2019). The systematic mapping provided a quantitative overview of the evidence, charting the distribution of studies by climate hazard, housing dimension, and geographic focus within Port Harcourt. The subsequent thematic synthesis involved a qualitative, indepth analysis of the findings from the mapped literature to develop analytical themes and answer the specific research questions.

➢ *Data Sources and Search Strategy*

A comprehensive and reproducible search strategy was implemented to identify the 22 relevant literature published up to August 2025 (see Appendix 1). The searches were conducted in major academic databases, including Scopus, Web of Science, Google Scholar, ScienceDirect, and African Journals Online (AJOL). Additionally, the search was not restricted by publication date to capture the full historical context. To achieve the search, a structured Boolean search query was developed using key terms and their synonyms grouped into three core concepts.

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Table 1: Boolean Search Query

Concept 1 (Geography):	"Port Harcourt," "Niger Delta," "Rivers State," "Nigeria."
Concept 2 (Climate Hazards):	"Climate change," "flood*," "sea level rise," "coastal erosion," "extreme rainfall," "heat stress," "temperature increase," "humidity."
Concept 3 (Housing):	"Housing quality," "build*," "dwell*," "structur*," "material," "thermal comfort," "indoor air quality," "moisture," "mold," "sanitation," "infrastructure," "adaptation," "retrofit."

However, to mitigate publication bias and include locally relevant data, a systematic search for grey literature was conducted in line with Hopewell, Clarke & Mallett (2005). This included reports from Nigerian government agencies (e.g., the Nigerian Meteorological Agency (NiMet), Rivers State Ministry of Environment, Niger Delta Development Commission), theses and dissertations from Nigerian universities, and publications from international organizations (e.g., World Bank, UN-Habitat, IPCC).

➢ *Study Selection and Eligibility Criteria*

The study selection process involved a two phase screening against predefined eligibility criteria to ensure the inclusion of relevant and high quality studies.

Table 2: Eligibility Criteria

Inclusion Criteria	Exclusion Criteria
Studies focusing empirically or theoretically on Port Harcourt or the Niger Delta with directly applicable findings.	Studies focused solely on agriculture, ecosystems, or broad economic impacts without a clear link to urban housing.
Literature discussing any climate hazard and its link to any dimension of housing quality, building integrity, or infrastructure.	General climate studies on Nigeria without specific analysis or data for the Port Harcourt/Niger Delta region.
Studies examining socio-economic factors, adaptation strategies, or policy measures related to climate resilience in the urban housing sector.	Opinion pieces or editorials without empirical or referenced analysis.
Publications in English.	

The screening process had two processes, phase one and phase two. In phase one, the title and Abstract were screened and all identified records were screened based on their titles and abstracts. Whereas phase two included a full text screening, where the full texts of potentially relevant studies were retrieved and assessed for eligibility against the criteria. This process was documented using a PRISMA (Preferred Reporting Items for Systematic Reviews) flow diagram to ensure transparency and reproducibility (see Appendix 1).

➢ *Data Extraction and Analysis*

Data from the final included studies were extracted into a standardized coding framework developed in a spreadsheet (see Appendix). The extraction template was designed to directly map onto the research questions and included the following fields:

- Bibliographic Information: Author, year, title, source.
- Study Characteristics: Research design (e.g., case study, survey, modelling), methodology (qualitative, quantitative, mixed methods), spatial focus within Port Harcourt.
- Climate Hazards (RQ1): Type of hazard studied, reported trends in frequency/intensity, and geographic scope.
- Housing Quality Impacts (RQ2): Reported effects on each predefined dimension: structural integrity, material durability, thermal comfort, moisture control/mold, sanitation functionality, and overall habitability.
- Mediating Factors (RQ3): Documented socio-economic (income, poverty), institutional (governance, policy), and tenure related factors that influence vulnerability.
- Adaptation Measures (RQ4): Reported homeowner, community, or policy level adaptation, retrofitting, or mitigation measures, and any reported evidence of their effectiveness.
- Methodological Gaps (RQ5): Noted limitations in the study's own methodology or identified gaps in the broader field.

In line with Braun and Clarke (2006), the qualitative data extracted were analyzed thematically. This involved the repeated reading of the extracted data (familiarization), generating initial codes from the data (coding), collating codes into potential themes that directly addressed the research questions (theme development), and ensuring themes accurately represented the dataset and clearly articulated the pathways between climate hazards, housing quality, and mediating factors (theme review and refinement).

➢ *Ethical and Rigor Considerations*

To ensure the rigor and trustworthiness of the synthesis, several measures were implemented. First off, a second researcher independently coded a random sample (20%) of the included studies to check for consistency in the application of the extraction framework. Additionally, emerging themes and interpretations were discussed regularly with subject matter experts to challenge assumptions and enhance analytical depth. Lastly and most importantly, the methodology and findings are reported with sufficient detail to allow for replication and critical appraisal.

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This systematic and transparent methodology ensures that the synthesis is comprehensive, minimizes bias, and provides a firm foundation for answering the research questions and identifying critical pathways for future research and policy intervention (Suri & Clarke, 2009).

IV. RESULTS

A. Documented Climate Hazards and Their Changing Characteristics

The literature consistently identifies a multi hazard environment in Port Harcourt, dominated by flooding, extreme heat, and sea level rise, with drivers rooted in both global climate change and local anthropogenic factors.

➢ *Flooding*

Flooding is the most extensively documented and recurrent hazard (see Appendix 4). It is not a monolithic threat but a combination of pluvial (from intense rainfall), fluvial (river overflow), and tidal influences (Ekanade et al., 2008; Greenwalt et al., 2021). Studies indicate an escalating trend in frequency and intensity. For instance, Chiadikobi et al. (2011) identified 2006 as a severe flood year within a decade (1998-2007) that saw seven high risk flood years. Ayotamuno (2020) reported peak annual rainfall reaching 2790 mm in 2007, while recent studies like Wachukwu et al. (2020) and Leka et al. (2025) noted even more increasing rainfall intensity. The primary drivers are twofold; climatic, through heavier, more concentrated rainfall (Ekanade et al., 2011; Amadi, 2024), and anthropogenic, through inadequate drainage (44.2% of respondents in Wachukwu et al., 2020 cited "no drainage facility"), impervious surfaces, and the blockage of natural waterways by waste (Akukwe, 2014).

Fig 2: Submerged Properties in Port Harcourt as a Result of Flash Flood After Heavy Rainfall (Amadi, 2024)

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Fig 3: A Flooded Property in Port Harcourt After Heavy Rainfall (Amadi, 2024)

➢ *Extreme Heat and the Urban Heat Island (UHI) Effect*

Rising temperatures and the UHI effect are also well established in the findings. Remote sensing studies reveal an alarming increase in Land Surface Temperature (LST). Peace et al. (2019) documented a mean LST rise from 30.2°C in 1986 to 35.3°C in 2018—a +5.1°C increase over 33 years. Leka et al. (2025) reported an even steeper increase of +8°C in mean LST between 2015 and 2024. This warming is worsened by the loss of vegetation and expansion of impervious surfaces, which grew from 78% to 93% of the study area between 2015 and 2024 (Leka et al., 2025). Field measurements by Shaibu and Utang (2013) and Peace et al. (2019) confirm that these surface temperatures translate into dangerous levels of human heat stress, particularly in commercial and high density residential areas, with the Heat Index frequently reaching "Extreme Caution" and "Danger" levels, especially during the late dry season (January-March).

➢ *Sea-Level Rise and Driving Rain*

Projections from the included studies indicate a serious threat from sea level rise. For instance, Ekanade et al. (2008) and Ekanade et al. (2011) warn that just a 1-meter rise could submerge large parts of Port Harcourt's coastal settlements, with saltwater intrusion compromising building materials and freshwater resources. Furthermore, the city's high rainfall intensity combines with prevailing southwest winds to create driving rain, identified by Budnukaeku and Francis (2022) as a specific hazard that directly damages building façades, leading to defacement, dampness, and accelerated material deterioration.

Table 3: Documented Climate Hazards and Key Characteristics in Port Harcourt

Hazard	Reported Trends & Intensity	Key Drivers	Primary Sources
Flooding	Increased frequency & intensity; inundation depths of 66-150cm recorded.	Heavy rainfall, inadequate/blocked drainage, impervious surfaces, low-lying topography.	Akukwe (2014); Chiadikobi et al. (2011); Wachukwu et al. (2020)
Extreme Heat/UHI	Mean LST increase of +5.1°C (1986-2018); Heat Index frequently in "Danger" zone.	Loss of vegetation, expansion of builtup areas, anthropogenic heat.	Leka et al. (2025); Peace et al. (2019); Shaibu & Utang (2013)
Sea-Level Rise	Projected 1m SLR could submerge coastal settlements.	Global climate change, regional subsidence.	Ekanade et al. (2008); Ekanade et al. (2011)
Driving Rain	Defaces building façades; causes dampness and soil creep.	High intensity rainfall combined with prevailing winds.	Budnukaeku & Francis (2022)

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B. Impacts of Climate Hazards on Housing Quality Dimensions

The synthesized evidence reveals a complex web of impacts across all dimensions of housing quality, with flooding and heat acting as the primary damaging agents (see Appendix 5).

➢ *Structural Integrity and Material Durability*

The findings from the study reveal that flooding is the primary agent of structural damage (Appendix 5). Inundation saturates foundation soils, leading to subsidence, cracked walls, and in severe cases, building collapse (Ikechukwu, 2015; Daminabo & Enwin, 2015). Wachukwu et al. (2020) quantified extensive damage from the 2019 floods, with numerous households reporting and incurring costs for repairing cracked walls. The driving rain contributed to this degradation by eroding wall surfaces and accentuating soil creep around foundations, which 80% of respondents linked to weakened structural strength (Budnukaeku & Francis, 2022).

Material durability on the other hand, is compromised through multiple pathways. Floodwaters for one, causing fading of paints, deterioration of wall finishes, and corrosion of metal components (Ikechukwu, 2015). Additionally, the use of low quality, water sensitive finishes like emulsion paint (47.4% of properties, Amadi, 2024) worsens the damage. Driving rain directly washes out paint and surface particles, accelerating façade defacement (Budnukaeku & Francis, 2022). While core structural materials like concrete blocks (96.8% of properties) are relatively resilient, the finishes and ancillary materials suffer significantly, reducing the overall service life of housing units.

➢ *Thermal Comfort, Moisture Control, and Mold*

Extreme heat profoundly impacts thermal comfort, as the high LST and Heat Index translate into oppressive indoor conditions, especially in informal settlements with corrugated iron roofs and poor ventilation, according to Tari et al. (2015) and Okibe (2025). In the study by Greenwalt et al. (2021), the residents report adaptive behaviors like frequent cold baths and sleeping outdoors just to cope.

Moisture and mold are also direct consequences of flooding and driving rain affecting thermal comfort and housing quality. The persistent dampness from inundation and waterlogged soils creates ideal conditions for mold growth, which is widely implicated in respiratory illnesses (Okibe, 2025; Ayotamuno, 2020). While few studies directly measure mold prevalence, the widespread reporting of dampness, like the 80% of respondents in Budnukaeku & Francis (2022), and its health implications strongly indicate a severe and widespread problem.

➢ *Sanitation Functionality and Overall Habitability*

Housing quality is affected by flooding, which in turn catastrophically disrupts sanitation. It causes septic tanks and soakaways to overflow, contaminating water sources and leading to outbreaks of waterborne diseases like cholera and typhoid, according to Ayotamuno (2020) and Ikechukwu (2015). Greenwalt et al. (2021) also found that fecal sludge management is virtually non existent in low income waterfront communities, with waste directly entering the environment, a situation severely worsened during floods.

The overall habitability of housing is therefore severely degraded with the convergence of structural damage, oppressive heat, mold proliferation, and sanitation failures, creating a living environment that threatens health, safety, and wellbeing. This is most acute in low income, informal settlements where these hazards compound preexisting deficits in services and infrastructure (Okibe, 2025; Greenwalt et al., 2021).

Table 4: Impacts of Climate Hazards on Specific Housing Quality Dimensions

Housing Quality Dimension	Impact of Flooding	Impact of Extreme Heat	Impact of Driving Rain
Structural Integrity	Foundation undermining, cracked walls, collapse.	(Not a primary direct impact)	Soil creep, erosion around foundations.
Material Durability	Corrosion, paint fading, finish degradation.	Thermal degradation of materials.	Façade defacement, loss of surface finish.
Thermal Comfort	(Secondary impact via dampness)	Severe reduction in comfort; increased indoor temperatures.	(Not a primary direct impact)
Moisture Control / Mold	Severe dampness, high mold risk.	(Not a primary direct impact)	Damp walls, increased mold risk.
Sanitation Functionality	Overwhelming of septic systems, water contamination.	(Not a primary direct impact)	(Not a primary direct impact)
Overall Habitability	Displacement, property loss, health risks.	Heat stress, reduced productivity, health risks.	Increased maintenance costs, damp living conditions.

C. Socio-Economic, Institutional, and Tenure Factors Mediating Impacts

The impacts of climate hazards are not distributed equally but are mediated by a range of factors that heighten the vulnerability of specific groups (Appendix 6).

➢ *Socio-Economic Factors*

Income and poverty are the strongest mediators in the assessment of climate change impact on housing quality in Port Harcourt. Low income households, like those in the Diobu area, are disproportionately concentrated in high risk flood zones and informal settlements, living in housing

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constructed with makeshift materials (Okibe, 2025). Often times, they lack the financial capacity for proactive adaptation or rapid recovery. Second to this is education, which also plays a critical role, since higher educational attainment in the studies is linked to a greater willingness and ability to undertake adaptive measures (Okunola et al., 2022; Amadi, 2024).

➢ *Institutional and Governance Factors*

A consistent theme across the literature is institutional failure. This includes a lack of enforcement of building codes and planning regulations, allowing construction on floodplains and drainage paths (Akukwe, 2014; Daminabo & Enwin, 2015; Amadi, 2024). Critical infrastructure deficits, particularly in drainage, are flagged by Wachukwu et al. (2020) as a primary cause of flooding. Furthermore, government responses are often reactive (post disaster relief) rather than proactive, and a "deep trust deficit" exists between communities and the state (Greenwalt et al., 2021).

➢ *Tenure Related Factors*

Tenure insecurity is another key mediator. The findings from Amadi's 2024 study show the high proportion of tenants (83.5%) disincentivizes investment in structural adaptations, as they are unable to modify properties and bear no longterm ownership risk. Whereas homeowners are 3.5 times more likely to stay and adapt than tenants (Amadi, 2024). Informal settlers face the dual threat of climate hazards and forced evictions, as evidenced by state led demolitions in waterfront communities (Greenwalt et al., 2021), which destroys any incremental improvements they make.

D. Documented Adaptation and Retrofitting Measures and Their Effectiveness

➢ *Household and Community Level Measures*

At the household level, adaptation is largely reactive and nonstructural. The most common measures include repositioning furniture (93.4% uptake, Amadi, 2024), using sandbags or temporary barriers, and raising doorsteps (Greenwalt et al., 2021). For heat, coping strategies include frequent bathing and sleeping outdoors. Some structural measures are observed, such as elevating land (44% of properties) and using water resistant finishes, though their uptake is lower and strongly correlated with income and ownership (Amadi, 2024). Community level actions include collective drain cleaning and the formation of neighborhood committees to manage waste and levy fines (Greenwalt et al., 2021).

➢ *Policy Level Measures and Effectiveness*

Policy recommendations abound in the literature, but evidence of effective implementation is scarce. Recommended measures include the construction of modern drainage systems, urban greening to mitigate UHI, enforcement of zoning laws, and the development of a coastal zone management plan (Ekanade et al., 2008; Peace et al., 2019; Akukwe, 2014). However, studies consistently report a gap between policy and practice. The reliance on churches and NGOs for post flood assistance, rather than robust government action, highlights this implementation failure (Wachukwu et al., 2020).

Most importantly, the effectiveness of the overall adaptation regime is questionable. Amadi and Adeniyi (2025) computed a Resilience Index (RI) for properties across flood zones and found no statistically significant difference in RI between low, moderate, and high flood exposure areas. This indicates systemic maladaptation—those at highest risk are not necessarily more resilient, highlighting the ineffectiveness of current efforts to reduce vulnerability.

Table 5: Adaptation Measures and Indicated Effectiveness

Level of Adaptation	Example Measures	Reported Uptake/Evidence	Indicated Effectiveness
Household/Reactive	Repositioning furniture, raised doorsteps, temporary barriers, frequent bathing.	Very high (e.g., 93.4% for repositioning furniture).	Low to moderate; temporary coping, does not address root causes.
Household/Structural	Elevated floors, water resistant wall/floor finishes, raised electrical sockets.	Low to moderate; highly dependent on income and tenure.	Moderate to High (where implemented) but constrained by affordability.
Community Led	Collective drain cleaning, community fines for dumping, community mapping.	Documented in specific cases (e.g., waterfront communities).	Moderate; can be effective locally but lacks scale.
Policy/Institutional	Drainage construction, urban greening, enforcement of building codes, relocation plans.	Mostly recommended, with limited documented implementation.	Low; significant gap between policy and practice.

E. Measurement and Methodological Gaps in the Literature

The review identified several methodological limitations that constrain a full understanding of the climate-housing nexus in Port Harcourt (Appendix 9). First, there is a dominance of single hazard studies and a lack of research on compound risks. Studies typically focus on flooding or heat or driving rain, failing to capture how these hazards interact to degrade housing. For instance, the combined effect of flood induced dampness and high temperatures on mold proliferation is not quantitatively explored.

Second, there is a scale disconnect. While remote sensing studies (e.g., Leka et al., 2025; Peace et al., 2019) provide excellent city scale data on LST and land use, they are not coupled with building level or household surveys to

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link these environmental changes to specific housing conditions, indoor temperatures, or health outcomes. Third, reliance on cross sectional and perception based data is a major limitation. Most studies are snapshots in time, relying on household surveys and self reported damage, which are subject to recall bias (Wachukwu et al., 2020; Ikechukwu, 2015). There is a critical absence of longitudinal studies to track the cumulative degradation of housing stocks and the longterm effectiveness of adaptations.

Fourth, there is a dearth of technical, building level measurements, as no studies were found that quantitatively measured mold spore counts, indoor humidity levels, material corrosion rates, or structural integrity through engineering assessments. Research on thermal comfort lacks indoor temperature and humidity monitoring (Shaibu & Utang, 2013; Peace et al., 2019). Finally, there is a notable gap in evaluating adaptation effectiveness. While many studies prescribe solutions, none were found that conducted rigorous before-and-after evaluations or cost benefit analyses of specific retrofitting measures in the Port Harcourt context (Amadi, 2024; Amadi & Adeniyi, 2025). This leaves policymakers without evidence based guidance on which interventions are most viable.

V. DISCUSSION OF FINDINGS

The findings of this systematic assessment confirm that Port Harcourt's housing sector is embedded in a multi hazard environment in which flooding, extreme heat (UHI), and sea level rise operate both independently and interactively to degrade housing quality. Across the reviewed studies there is strong convergence on the primacy of flooding as the most immediate and documentable driver of structural damage and habitability loss (Akukwe, 2014; Chiadikobi et al., 2011; Wachukwu et al., 2020). At the same time, remote sensing and field microclimate studies consistently document substantial warming and urban heat island effects (Peace et al., 2019; Leka, Gbarabe, & Dagogo, 2025; Shaibu & Utang, 2013) that compound moisture related problems and create separate pathways to decreased indoor comfort, higher energy demand, and health risk. Where divergence appears, it is less about the existence of hazards than about magnitude and measurement: remote sensing reports of LST change vary in temporal resolution and magnitude (Peace et al., 2019; Leka et al., 2025), and flood depth and damage estimates vary with sampling strategy and event selection (Chiadikobi et al., 2011; Wachukwu et al., 2020). Nevertheless, the overall pattern is unambiguous: multiple, overlapping climatic stressors interact with local anthropogenic processes to erode housing quality.

Interpreted through the IPCC risk framework—where risk arises from hazards interacting with exposure and vulnerability (IPCC, 2022)—the evidence shows classic amplification by exposure and social vulnerability. Port Harcourt's rapid, largely informal urban expansion has concentrated low income households in low lying, poorly serviced floodplains (Echendu, 2025; Greenwalt et al., 2021), increasing exposure. At the same time, socio-economic and tenure mediators—poverty, tenant prevalence, weak tenure security, and limited access to finance—reduce adaptive capacity and investment in durable retrofits (Okibe, 2025; Amadi, 2024; Okunola, Simatele, & Olowoporoku, 2022). The empirical finding that owners are far more likely to invest in structural measures (Amadi, 2024), and that resilience indices do not scale with exposure (Amadi & Adeniyi, 2025), illustrates how vulnerability, not hazard magnitude alone, determines outcomes. This aligns with conceptual expectations of the IPCC framework and highlights the policy leverage of interventions that reduce vulnerability (e.g., tenure security, finance) as well as exposure (e.g., managed retreat, zoning).

A critical insight from the synthesis is the compound nature of damage pathways, where flooding undermines foundations, leads to prolonged dampness and mold risk, and overwhelms sanitation systems, while driving rain accelerates façade deterioration and soil creep; concurrently, UHI raises indoor heat exposures and can intensify health impacts from damp related respiratory problems (Budnukaeku & Francis, 2022; Ikechukwu, 2015; Peace et al., 2019). Few studies, however, quantify these interactions empirically. The literature is therefore rich in documented individual hazard impacts but thin on mechanistic studies of hazard interaction (e.g., how elevated indoor humidity under high temperatures affects mold proliferation and occupant health). This gap matters because interventions that address a single hazard (e.g., drainage) may fail if co-occurring heat and moisture drivers are unaddressed; conversely, integrated measures (green infrastructure) can simultaneously reduce flood peaks, lower LST, and improve evapotranspiration—making multisectoral responses more cost effective (Leka et al., 2025; Peace et al., 2019).

Policy and governance emerge across the corpus as central determinants of whether adaptation is feasible or equitable. Studies repeatedly document weak enforcement of building codes, absence of authoritative flood maps, reactive relief based responses, and exclusion of informal settlements from service provision (Akukwe, 2014; Greenwalt et al., 2021; Amadi, 2024). Where community level initiatives (e.g., mapping by CMAP/Chicoco) influenced project design and inclusion (Greenwalt et al., 2021), positive policy traction was observed; yet these remain localized wins rather than systemic reform. The implication is that enhancing housing resilience requires institutional reforms: authoritative hazard mapping, inclusionary planning, enforcement of land use controls coupled with compensatory and relocation strategies that are socially just, and financing mechanisms that lower barriers to structural retrofits for tenants and low income owners.

The evidence on adaptation uptake reveals that household and community adaptations are predominately reactive, simple, and high in uptake (repositioning furniture, temporary barriers) but limited in protective value (Amadi, 2024; Okunola et al., 2022). More protective structural measures—elevation, water repellent finishes, pumps—have demonstrable technical value where implemented but are constrained by affordability, tenure, and information (Amadi & Adeniyi, 2025). Critically, empirical studies document

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maladaptation or mismatch: resilience indices do not differ significantly across exposure classes, indicating that those at highest risk are not necessarily better protected (Amadi & Adeniyi, 2025). This points to a distributional failure, where market signals alone will not deliver equitable resilience, and public policy must subsidize or incentivize measures that private households cannot afford.

Methodologically, the review exposes important research weaknesses that limit policy guidance. High quality remote sensing provides robust spatial diagnostics of UHI and land cover change (Peace et al., 2019; Leka et al., 2025), but it is seldom linked to household level thermal, health, or material degradation metrics. Quantitative household surveys are abundant but frequently cross sectional, perception based, and unlinked to longitudinal damage records or engineering assessments (Wachukwu et al., 2020; Ikechukwu, 2015). Few studies undertake controlled before-after evaluations or cost benefit analyses of retrofits—an empirical vacuum that leaves policymakers without evidence of which interventions delivers the greatest welfare gains per naira invested (Amadi, 2025). Addressing this requires mixed method longitudinal designs, instrumented building monitoring (indoor temperature, humidity, material moisture and corrosion rates), and trialed retrofit interventions with economic evaluation.

Practically, the findings imply a three pronged adaptation strategy for housing policy in Port Harcourt. First, reduce exposure through spatial planning—authoritative flood mapping, stringent enforcement in high risk zones, and planned relocation or resilient reconstruction where necessary (Chiadikobi et al., 2011; Ugwu et al., 2022). Second, reduce vulnerability by improving tenure security, expanding access to microfinance or subsidy schemes for retrofits, and integrating informal settlements into service delivery (Greenwalt et al., 2021; Amadi, 2024). Third, adopt integrated nature based and engineering approaches—urban greening, SuDS, cool roofs and targeted elevation—that simultaneously address flooding and heat (Leka et al., 2025). Importantly, these actions must be paired with robust monitoring and evaluation so that interventions are evidence based and adaptable.

In sum, this body of literature establishes that climate change is already degrading housing quality in Port Harcourt through multiple interacting pathways, and that social and institutional factors determine who bears the damage and who can adapt. Theoretical expectations from the IPCC risk framing are largely validated: hazards translate into housing risk through exposure and vulnerability. To move from diagnosis to durable improvement requires bridging the methodological gaps—linking city scale environmental diagnostics with building scale measurements and longitudinal socio-economic tracking—and reframing policy to prioritize inclusive, integrated interventions that address both physical hazards and the socio-economic barriers to adaptation.

VI. CONCLUSION

The overarching conclusion of this study is that climate change is already exerting a profound and multi layered impact on housing quality in Port Harcourt, with the most vulnerable populations living in informal and low lying settlements experiencing the greatest risks. By systematically disaggregating housing into structural, material, thermal, moisture, sanitation, and habitability dimensions, this research highlights the multiple, overlapping damage pathways that erode urban resilience. The analysis confirms that hazards alone do not determine outcomes; rather, the intersection of exposure, socioeconomic vulnerability, and weak governance drives the scale and severity of housing degradation. The contribution of this study lies in moving beyond generic vulnerability assessments to provide a fine grained, city specific synthesis that clarifies where and how interventions should be targeted. Ultimately, this work contributes to knowledge by offering a comprehensive evidence base that integrates environmental hazards with social and institutional mediators, thereby equipping policymakers, practitioners, and scholars with a clearer roadmap for building climate resilient housing systems in African coastal cities. The following recommendations are proposed:

- *Policy Recommendations:*

Policymakers at both state and federal levels should prioritize the integration of climate resilience into housing and urban development plans. First, authoritative flood and hazard maps must be developed and enforced to guide settlement planning, complemented by zoning regulations that prevent construction in high risk floodplains. Second, investments in critical infrastructure such as drainage, sanitation systems, and urban greening should be scaled up to simultaneously mitigate flooding and heat stress. Third, tenure reforms and pro-poor financing schemes, including subsidies, microcredit, or insurance for housing retrofits, are essential to enable low income households and tenants to adopt protective measures. Finally, institutional capacity must be strengthened to move from reactive disaster relief to proactive risk management through coordinated, transparent, and inclusive governance.

- *Practical Recommendations:*

Practitioners in the housing and construction sector should adopt and mainstream climate resilient building technologies, including elevated foundations, water resistant finishes, ventilation enhancing designs, and cool roofing systems. Community level initiatives such as collective drain maintenance, participatory hazard mapping, and neighborhood resilience committees should be supported and scaled up to enhance grassroots adaptive capacity. NGOs and civil society actors can play a bridging role by piloting retrofit interventions and documenting their effectiveness, thereby providing practical evidence for policymakers and communities alike.

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➢ *Theoretical/Academic Recommendations:*

The IPCC risk framework has proven valuable in situating housing risk at the nexus of hazard, exposure, and vulnerability, but the findings point to the need for more compound risk models that account for interactions between flooding, heat, and dampness in shaping housing outcomes. Scholars should refine climate-housing frameworks by integrating engineering perspectives with socio-economic analysis, enabling a more holistic understanding of material degradation, health, and governance. Furthermore, resilience indices need to be reconceptualized to better capture not only physical robustness but also distributional equity in adaptation outcomes.

It is important to note that this research is limited by its reliance on secondary data drawn from published and grey literature, which constrains the ability to generate new empirical evidence. The predominance of cross sectional and perception based studies in the evidence base introduces recall and reporting biases, while the absence of longitudinal and engineering based data restricts the ability to track housing degradation or rigorously evaluate adaptation effectiveness over time. Furthermore, the concentration of available studies in certain neighborhoods may mean that spatial variations in hazard exposure and adaptive capacity across Port Harcourt are not fully captured. These limitations imply that while the synthesis provides a robust overview of climate-housing interactions, its generalizability to all housing typologies and future projections remains somewhat constrained.

Therefore, future research should adopt longitudinal, mixed method designs that couple remote sensing with building level engineering assessments and household surveys to provide more precise, time sensitive evidence on housing degradation pathways. Controlled evaluations of adaptation measures, including cost benefit analyses of structural retrofits such as elevated floors, cool roofing, and drainage improvements, are particularly needed to inform cost effective interventions. Research should also focus on the compound effects of multiple hazards, especially the interaction of flooding and extreme heat in exacerbating dampness, mold, and health risks. Finally, comparative studies across Nigerian and other African coastal cities would provide valuable insights into the transferability of interventions and enable the development of more generalized, context sensitive frameworks for climate-resilient housing.

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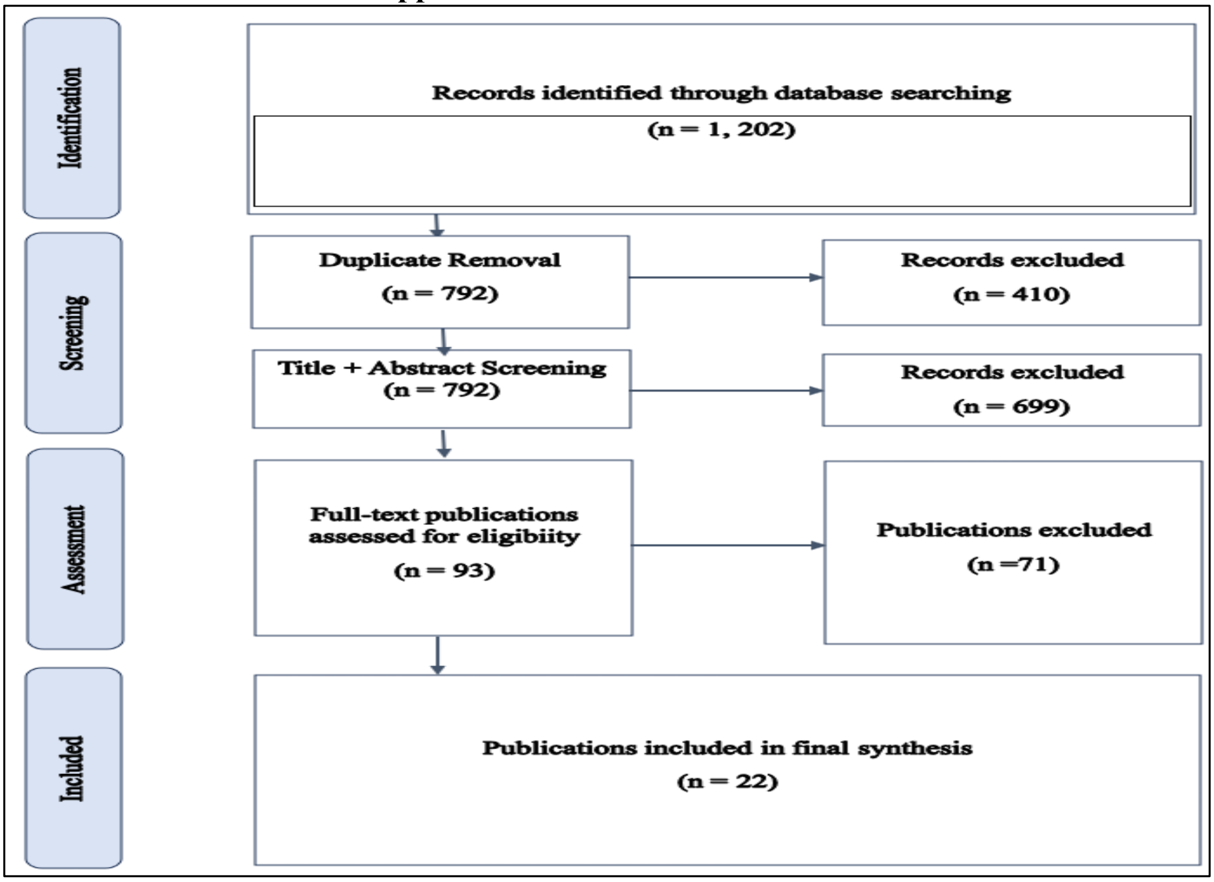
APPENDIX

Appendix 1: PRISMA Flow Chart



Appendix 2: Climate Data for Port Harcourt (1991-2020) NOAA (2020)

Climate data for Port Harcourt (1991–2020) [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	37 (99)	38.5 (101.3)	38 (100)	36.2 (97.2)	37.2 (99.0)	34 (93)	32.5 (90.5)	33 (91)	33.1 (91.6)	39 (102)	35.2 (95.4)	37.2 (99.0)	39.0 (102.2)
Mean daily maximum °C (°F)	33.1 (91.6)	34.0 (93.2)	33.2 (91.8)	32.6 (90.7)	31.9 (89.4)	30.2 (86.4)	29.0 (84.2)	28.9 (84.0)	29.6 (85.3)	30.5 (86.9)	31.8 (89.2)	32.7 (90.9)	31.5 (88.7)
Daily mean °C (°F)	27.2 (81.0)	28.4 (83.1)	28.4 (83.1)	28.0 (82.4)	27.6 (81.7)	26.6 (79.9)	25.9 (78.6)	25.8 (78.4)	26.2 (79.2)	26.7 (80.1)	27.3 (81.1)	27.2 (81.0)	27.1 (80.8)
Mean daily minimum °C (°F)	21.3 (70.3)	22.8 (73.0)	23.5 (74.3)	23.5 (74.3)	23.3 (73.9)	22.9 (73.2)	22.7 (72.9)	22.8 (73.0)	22.9 (73.2)	22.8 (73.0)	22.9 (73.2)	21.8 (71.2)	22.8 (73.0)
Record low °C (°F)	11.6 (52.9)	16.7 (62.1)	16 (61)	15.9 (60.6)	16.4 (61.5)	19 (66)	19 (66)	19.6 (67.3)	12.5 (54.5)	19.5 (67.1)	18 (64)	15 (59)	11.6 (52.9)
Average precipitation mm (inches)	22.1 (0.87)	59.7 (2.35)	114.6 (4.51)	159.2 (6.27)	260.9 (10.27)	310.1 (12.21)	357.9 (14.09)	290.2 (11.43)	354.0 (13.94)	251.7 (9.91)	87.2 (3.43)	19.0 (0.75)	2,286.5 (90.02)
Average precipitation days (≥ 1.0 mm)	1.8	3.6	8.0	10.0	14.2	16.6	19.2	19.2	19.0	16.0	6.9	1.4	135.9
Average relative humidity (%)	78.1	81.7	87.3	89.1	90.0	91.0	91.1	90.7	91.4	90.9	88.1	80.7	87.5
Mean monthly sunshine hours	142.6	123.2	114.7	132.0	139.5	102.0	77.5	74.4	78.0	102.3	132.0	148.8	1,367

Appendix 3: Study Characteristics

Author(s) (Year)	Methodology
Okibe, S. (2025)	Qualitative case study with household survey (Diobu, Eagle Island).
Tari, E., Brown, I., & Chikagbum, W. (2015)	Case study; mixed-methods (primary & secondary data).
Leka, O. A., Gbarabe, F. O., & Dagogo, S. (2025)	Longitudinal remote-sensing / GIS comparative analysis (Landsat LST, NDVI; quantitative spatial methods).
Okunola, O. H., Simatele, M. D., & Olowoporoku, O. (2022)	Quantitative household survey (structured questionnaire; statistical analysis: ANOVA, regression).
Ekanade, O., Ayanlade, A., & Orimoogunje, O. O. I. (2011)	Climate-modelling / scenario study (MAGICC–SCENGEN) with GIS downscaling (quantitative).
Shaibu, V. O., & Utang, P. B. (2013)	Field-based quantitative microclimate study (instrumentation: Kestrel tracker; Heat Index, ANOVA, regression).
Daminabo, F. O., & Enwin, A. D. (2015)	Conceptual/analytical paper with case examples and field observations (qualitative/descriptive).
Abimaje, J., & Akingbohungbe, D. O. (2013)	Conceptual literature review / position paper (qualitative synthesis).
Ekanade, O., Ayanlade, A., & Orimoogunje, I. O. O. (2008)	Climate-modelling & geospatial impact assessment (MAGICC–SCENGEN; IDW downscaling; quantitative GIS).
Greenwalt, J., Dede, M., Johnson, I., et al. (2021)	Mixed-methods community case study: participatory mapping, household surveys, transect walks, focus groups (qual + quant).
Ikechukwu, E. E. (2015)	Empirical case study: structured household survey + field observation and mapping (quantitative descriptive).
Budnukaeku, A. C., & Francis, I. G. (2022)	Small observational study: perception survey (Likert) + photographic field inspection (quantitative descriptive + qualitative observation).
Peace, N., Ologunorisa, T. E., Nwagbara, M. O., & Vincent, O. N. (2019)	Remote-sensing / geospatial time-series analysis (LST extraction from Landsat; quantitative GIS/GEE).
Peace, N., Diagi, B. E., & Suzan, A. (2019)	Observational field study of human thermal comfort (instrumented air measurements; HI; geo-spatial analysis).
Amadi, A. (2025)	Explanatory quantitative survey with property inspection (descriptive statistics, cluster analysis, logistic regression).
Chiadikobi, K. C., Omoboriowo, A. O., et al. (2011)	Empirical flood-risk assessment: field mapping, soil lab testing, rainfall time-series analysis (mixed methods, quantitative emphasis).
Ayotamuno, A. (2020)	Longitudinal climate parameter analysis (time-series statistical analysis of NIMET data; quantitative).
Ugwu, M. O., Elenwo, E. I., Obafemi, A. A., & Eludoyin, O. S. (2022)	Spatial flood-vulnerability assessment (geospatial overlay, supervised classification, AHP weighting; quantitative GIS).
Amadi, A. (2024)	Case study with quantitative survey and on-site property inspection (descriptive + inferential ANOVA).
Amadi, A., & Adeniyi, O. (2025)	Cross-sectional quantitative property-level resilience survey; PCA for index construction; ANOVA.
Akukwe, T. I. (2014)	Cross-sectional empirical survey with PCA (quantitative questionnaire, PCA dimension reduction).
Wachukwu, F. C., Obinna, V. C., & Weje, I. I. (2020)	Cross-sectional mixed-methods household survey (quantitative dominant) plus qualitative review; Multiple Classification Analysis.

Appendix 4: Climate Hazards Studied

Author(s) & Year	Climate Hazard(s) Studied
Okibe, S. (2025)	Flooding; air pollution; extreme heat
Tari, E., Brown, I., & Chikagbum, W. (2015)	Flooding; air pollution; ecosystem/landscape degradation
Leka, O. A., Gbarabe, F. O., & Dagogo, S. (2025)	Urban heat / Land Surface Temperature (UHI); linked urban flooding vulnerability
Okunola, O. H., Simatele, M. D., & Olowoporoku, O. (2022)	Flooding (primary); storms; heat extremes; aridity/soil erosion (regional)
Ekanade, O., Ayanlade, A., & Orimoogunje, O. O. I. (2011)	Temperature rise; precipitation changes; sea-level rise; secondary: flooding, waterlogging
Shaibu, V. O., & Utang, P. B. (2013)	Heat stress / Urban heat (thermal hazard)
Daminabo, F. O., & Enwin, A. D. (2015)	Flooding (pluvial, fluvial, tidal); storm surge; drainage-related flooding
Abimaje, J., & Akingbohungbe, D. O. (2013)	Rising temperatures / UHI; erratic precipitation (flooding); sea-level rise; wind storms; water scarcity

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Author(s) & Year	Climate Hazard(s) Studied
Ekanade, O., Ayanlade, A., & Orimoogunje, I. O. O. (2008)	Warming (day/night); precipitation redistribution; sea-level rise; related flood risk
Greenwalt, J. et al. (2021)	Flooding (pluvial/tidal); heat/temperature rise; sea-level rise / salt intrusion; air pollution; water-/vector-borne health hazards
Ikechukwu, E. E. (2015)	Urban flooding (pluvial/flash/ponding)
Budnukaeku, A. C., & Francis, I. G. (2022)	Driving (wind-driven) rain — façade moisture damage; increased rainfall intensity
Peace, N., Ologunorisa, T. E., Nwagbara, M. O., & Vincent, O. N. (2019)	Urban heat / LST increases (heat hazard)
Peace, N., Diagi, B. E., & Suzan, A. (2019)	Urban heat / Heat Index (thermal hazard)
Amadi, A. (2025)	Flooding (property-level flood risk; depth-based exposure strata)
Chiadikobi, K. C. et al. (2011)	Flooding (pluvial/estuarine/fluvial) — rainfall intensity & low-lying drainage impacts
Ayotamuno, A. (2020)	Flooding linked to changing rainfall; rising temperatures (climatic trends)
Ugwu, M. O. et al. (2022)	Flooding (spatial flood-vulnerability mapping)
Amadi, A. (2024)	Flooding (property-level exposure and adaptation)
Amadi, A., & Adeniyi, O. (2025)	Urban flooding (property-level resilience to inundation)
Akukwe, T. I. (2014)	Flooding (drivers: heavy rainfall, urbanisation; flood occurrence determinants)
Wachukwu, F. C., Obinna, V. C., & Weje, I. I. (2020)	Flooding (2019 event focus; urban/ponding/overbank flooding)

Appendix 5: Summary of Housing Quality Impacts Studied

Author(s) & Year	Housing Quality Impacts
Okibe, S. (2025)	**Structural integrity:** makeshift/slum homes vulnerable to flood damage and collapse. **Material durability:** fragile materials (bamboo, palm) prone to failure. **Thermal comfort:** poor ventilation, corrugated roofs → heat stress. **Moisture/mold:** flood-driven damp and mold. Sanitation: poor infrastructure → health hazards. **Overall habitability:** overcrowding, lack of services → very poor living conditions.
Tari, E., Brown, I., & Chikagbum, W. (2015)	**Structural integrity:** slum dwellings prone to collapse in floods. **Material durability**: traditional/fragile materials degrade with extreme weather. **Thermal comfort:** inadequate ventilation and roofing → discomfort. **Moisture/mold:** flooding → damp/mold risk. Sanitation: weak services amplify health risks. **Overall habitability:** overcrowding and service deficits reduce livability.
Leka, O. A., Gbarabe, F. O., & Dagogo, S. (2025)	**Structural integrity**: not measured (no building-level data). **Material durability**: not measured. Thermal comfort: strong evidence — large LST rise (47→55°C) → worsening comfort/heat stress. **Moisture/mold:** not reported. **Sanitation**: not reported. **Overall habitability:** conceptually reduced by UHI and loss of greenery (no household metrics).
Okunola, O. H., Simatele, M. D., & Olowoporoku, O. (2022)	**Structural integrity:** floods damage low-income housing; wealthier dwellings more resilient. **Material durability:** poorer housing stock less durable. **Thermal comfort:** heat extremes affect informal settlements. **Moisture/mold:** flooding/poor drainage → moisture problems. **Sanitation**: service decline post-disaster. **Overall habitability:** informal areas suffer longer displacement and poorer recovery.
Ekanade, O., Ayanlade, A., & Orimoogunje, O. O. I. (2011)	**Structural integrity:** projected SLR and inundation threaten foundations/settlements (modelled—no field counts). **Material durability:** saltwater/ inundation imply accelerated deterioration (not measured). **Thermal comfort:** robust projected warming (~+3–4°C) → worse comfort. **Moisture/mold**: implied increase from wetter extremes (not measured). **Sanitation**: disruption risk from flooding (inferred). **Overall habitability:** high-risk of inundation, infrastructure loss, displacement.
Shaibu, V. O., & Utang, P. B. (2013)	**Structural integrity:** not studied.

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Author(s) & Year	Housing Quality Impacts
	Material durability: not assessed. **Thermal comfort:** measured HI shows commercial/high-density areas in extreme caution/danger → reduced comfort. **Moisture/mold:** high RH implies mold risk (not measured). **Sanitation**: not addressed. **Overall habitability:** heat significantly reduces comfort in dense zones.
Daminabo, F. O., & Enwin, A. D. (2015)	**Structural integrity:** flooding and poorly designed works can undermine/"swallow" buildings. **Material durability:** floodwaters accelerate decay/corrosion. **Thermal comfort:** not directly studied (flood-related dampness noted). **Moisture/mold**: inundation → damp/mold risk. **Sanitation**: drains/sewers overwhelmed → contamination. **Overall habitability**: severe disruption, displacement, health risk.
Abimaje, J., & Akingbohungbe, D. O. (2013)	**Structural integrity**: flooding/SLR and soil movement threaten foundations (conceptual). **Material durability**: thermal/moisture cycles reduce lifespan (conceptual). **Thermal comfort**: national warming → higher cooling needs; reduced comfort. **Moisture/mold**: increased flood/moisture risk implied. **Sanitation**: water scarcity + flooding → sanitation stress. **Overall habitability**: combined hazards threaten livability.
Ekanade, O., Ayanlade, A., & Orimoogunje, I. O. O. (2008)	**Structural integrity**: SLR/flooding threaten settlements (modelled implications). **Material durability**: salt intrusion/flooding imply deterioration (not measured). **Thermal comfort**: detailed temperature rises projected → worse comfort. **Moisture/mold**: implied via heavier rains/waterlogging. **Sanitation**: flooding → infrastructure disruption (inferred). **Overall habitability**: serious long-term risk from SLR and warming.
Greenwalt, J. et al. (2021)	**Structural integrity**: waterfront (reclaimed) settlements vulnerable to erosion/subsidence; demolitions compound risks. **Material durability**: saltwater and inundation accelerate corrosion/rot. **Thermal comfort**: residents report increased heat → coping behaviours. **Moisture/mold**: frequent flooding → damp/mold risks. **Sanitation**: severe failures (open drains, fecal flows) during floods. **Overall habitability**: degraded by floods, pollution, poor services; displacement common.
Ikechukwu, E. E. (2015)	**Structural integrity**: cracked walls, tilting foundations, occasional collapse after floods. **Material durability**: inundation accelerates material deterioration (paint, finishes). **Thermal comfort**: not measured. Moisture/mold: frequent waterlogging implies mold risk (not measured). **Sanitation**: soakaway/latrine overflows, water pollution. **Overall habitability**: income loss, displacement, reduced livability.
Budnukaeku, A. C., & Francis, I. G. (2022)	**Structural integrity**: perceptions that driving rain weakens structures (50% respondents). **Material durability**: high façade defacement, paint loss, surface erosion (90% respondents). **Thermal comfort**: qualitative notes (rain-exposed walls feel cooler). **Moisture/mold**: 80% report dampness after driving rain → mold risk. **Sanitation**: not primary focus. **Overall habitability**: increased maintenance cost, safety/erosion concerns.
Peace, N., Ologunorisa, T. E., et al. (2019)	**Structural integrity**: not reported. Material durability: not assessed. **Thermal comfort**: LST rise (+5.1°C since 1986) → many areas exceed comfort thresholds → higher heat-risk. **Moisture/mold**: not reported. **Sanitation**: not reported. **Overall habitability**: LST increases degrade comfort and raise public-health risks.
Peace, N., Diagi, B. E., & Suzan, A. (2019)	**Structural integrity**: not measured. Material durability: not measured. **Thermal comfort**: HI data show large portions of the year in extreme caution/danger → major comfort/health impact. **Moisture/mold**: not measured.

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Author(s) & Year	Housing Quality Impacts
	Sanitation: not measured. **Overall habitability**: heat substantially reduces livability in many land-use zones.
Amadi, A. (2025)	**Structural integrity**: blockwork dominates (more resilient); bungalows prevalent → exposure to inundation. **Material durability**: floor/finish types affect damage/recovery (unscreeded floors more vulnerable). Thermal comfort: not assessed. **Moisture/mold**: longer drying times imply mold risk (not measured). **Sanitation**: not reported. **Overall habitability**: interior damage, electrical hazards and slow water removal reduce habitability.
Chiadikobi, K. C. et al. (2011)	**Structural integrity**: measured flood marks (66–150 cm) → high risk to structures; collapse potential implied. **Material durability**: inundation threatens finishes/materials (not measured). Thermal comfort: not addressed. **Moisture/mold**: ponding/low permeability imply damp risk (not measured). **Sanitation**: not reported. **Overall habitability**: high inundation depths threaten usability and wellbeing.
Ayotamuno, A. (2020)	**Structural integrity**: roads, bridges and small buildings damaged; roofs lost in storms. **Material durability**: submersion accelerates deterioration. **Thermal comfort**: rising temps (32–36°C peaks) reduce indoor comfort. **Moisture/mold**: floods left mold/bacteria → respiratory illness. **Sanitation**: sewage/chemical contamination of water → health impacts. **Overall habitability**: neighborhoods uprooted; ventilation reduced in dense areas.
Ugwu, M. O. et al. (2022)	**Structural integrity**: mapped properties (12% highly vulnerable) at risk of foundation erosion/collapse. **Material durability**: flood exposure implies faster deterioration (not measured). **Thermal comfort**: not assessed. Moisture/mold: not measured (risk implied). **Sanitation**: not measured. **Overall habitability**: vulnerability maps identify properties likely to lose habitability during floods.
Amadi, A. (2024)	**Structural integrity**: many low-storey bungalows → vulnerability; elevation varies by exposure. **Material durability**: block/concrete common (relatively durable) but many finishes (emulsion paint) absorb water. **Thermal comfort**: not assessed. Moisture/mold: coping actions (remove rugs/wallpaper) imply moisture risk. **Sanitation**: not assessed. **Overall habitability**: high prevalence of coping; habitability threatened where adaptation is inadequate.
Amadi, A., & Adeniyi, O. (2025)	**Structural integrity**: resilience proxies (elevation, multistorey, concrete/block) preserve integrity (no failure counts). **Material durability**: water-resistant finishes reduce damage (used as indicators). **Thermal comfort**: not measured. Moisture/mold: removal/pumps as proxies to reduce mold risk (no prevalence data). **Sanitation**: not measured. **Overall habitability**: composite resilience index used as habitability proxy (higher RI → better habitability).
Akukwe, T. I. (2014)	**Structural integrity**: flooding and overflow undermines foundations → collapse risk (drivers identified). **Material durability**: repeated inundation accelerates deterioration (not measured). **Thermal comfort**: not studied. **Moisture/mold**: ponding implies damp/mold risk (not measured). **Sanitation**: blocked drains/overflow implicated in health risks. **Overall habitability**: flooding and poor drainage reduce livability in affected zones.
Wachukwu, F. C., Obinna, V. C., & Weje, I. I. (2020)	**Structural integrity**: cracked walls, building/road damage itemised (monetised losses). **Material durability:** tiles/finishes and furniture damaged → accelerated deterioration. T

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Author(s) & Year	Housing Quality Impacts
	hermal comfort: not addressed. **Moisture/mold**: dampness and ponding reported → mold risk. **Sanitation**: septic tank collapse and sanitation disruption recorded. **Overall habitability**: large-scale asset loss, access disruption and reduced livability; many affected households.

Appendix 6: Mediating Factors Studied

Author(s) & Year	Key Mediating Factors
Okibe, S. (2025)	Socio-economic: low income/poverty; Institutional: weak governance, poor infrastructure; Tenure: insecure/no legal title.
Tari, E., Brown & Chikagbum (2015)	Socio-economic: poverty, limited services; Institutional: lack of clean energy/waste/health infrastructure, weak planning; Tenure: insecure land rights.
Leka, Gbarabe & Dagogo (2025)	Urbanisation/uncoordinated development; loss of vegetation/imperviousness; anthropogenic heat/energy use; pollution (flaring, illegal refining); planning/policy gaps.
Okunola, Simatele & Olowoporoku (2022)	Socio-economic: income, education, age; Institutional: reactive govt., poor drainage/enforcement; Tenure: owners adapt more than renters.
Ekanade, Ayanlade & Orimoogunje (2011)	High coastal population exposure; economic dependence on fossil fuels (macro-vulnerability); limited national/local policy preparedness; implementation capacity gaps.
Shaibu & Utang (2013)	Land-use/density (high-density, low-income exposure); limited urban greening/ventilation policy (institutional).
Daminabo & Enwin (2015)	Rapid urbanisation; weak planning/enforcement; poor drainage project design; forced demolitions/tenure insecurity.
Abimaje & Akingbohungbe (2013)	Poverty/affordability constraints; material/resource choices; weak building regulations and enforcement; limited tenure discussion.
Ekanade, Ayanlade & Orimoogunje (2008)	Coastal population concentration; weak national adaptation planning; limited institutional preparedness; tenure mentioned peripherally.
Greenwalt et al. (2021)	Poverty/livelihood precarity; youth demographics; weak city governance & trust deficit; forced evictions; insecure tenure; exclusion from services.
Ikechukwu (2015)	Low incomes/occupation fragility; developers building on drainage; planning failures; inadequate drainage maintenance.
Budnukaeku & Francis (2022)	Weak construction standards/regulation; maintenance cost burden on occupants; limited socioeconomic data; tenure not examined.
Peace, Ologunorisa, Nwagbara & Vincent (2019)	Population growth/urban expansion; impervious surfaces/land-use change; institutional gaps in urban greening and land management.
Peace, Diagi & Suzan (2019)	Land-use/urban form (dense mixed-use); occupational exposure (vendors/workers); vulnerable groups (children, elderly); lack of greening/urban planning.
Amadi (2025)	Income, education, age, gender; tenure (owners more likely to adapt); low insurance uptake; affordability constraints; short residence durations.
Chiadikobi et al. (2011)	Rapid, uncoordinated urbanisation; poor waste disposal (blocked drains); low-lying topography and low soil permeability; weak planning.
Ayotamuno (2020)	Poverty in floodplain settlements; weak planning/enforcement; inadequate drainage investment; informal settlement tenure.
Ugwu et al. (2022)	Physical: proximity to rivers, low elevation, soil texture, built-up cover; urbanisation/imperviousness; governance/planning deficits (discussed).
Amadi (2024)	Affordability constraints; high tenant prevalence (limits retrofits); weak institutional maps/guidance; low insurance/market uptake of protective products.
Amadi & Adeniyi (2025)	Economic capacity (savings/insurance) and affordability; high property density/land pressure; lack of authoritative flood maps; weak institutional support; implied tenure effects.
Akukwe (2014)	Rapid population growth/migration; conversion to impervious surfaces; informal/illegal development; poor waste disposal; inadequate drainage and enforcement.
Wachukwu, Obinna & Weje (2020)	Income & livelihood vulnerability; high unemployment; inadequate drainage infrastructure (blockage/no drains); weak formal emergency response; settlement in low-lying/floodplains; tenure/inability to relocate.

Appendix 7: Adaptation Measures

Author(s) & Year	Key Adaptation Measures
Okibe, S. (2025)	Community: waste-to-wealth programmes, floating schools (Makoko). Policy: limited institutional support/funding noted.
Tari, E., Brown & Chikagbum (2015)	Policy: demolition of structures on drainage lines; levees/raised embankments (municipal flood control).
Leka, Gbarabe & Dagogo (2025)	Planning/policy: urban greening, cool roofs/pavements, improved urban design/airflow, energy efficiency, watershed management, integrate climate into EIA.
Okunola, Simatele & Olowoporoku (2022)	Household: relocation, repairs, drain cleaning, mutual aid Community: local drainage works Policy: storm barriers, DRR mechanisms (low uptake).
Ekanade, Ayanlade & Orimoogunje (2011)	Policy: coastal zone management plan; national/regional adaptation strategy and mainstreaming into development planning.
Shaibu & Utang (2013)	Policy/urban: tree planting/urban vegetation, improved spatial planning and ventilation, energy-conserving building design.
Daminabo & Enwin (2015)	Policy/infrastructure: SuDS, re-contouring, canalization, dual carriageway water tunnels Building: elevated construction, flood-resistant walls Community: evacuation camps, early warning.
Abimaje & Akingbohungbe (2013)	Design/tech: passive solar/ventilation, elevated living spaces, rainwater harvesting, use low-embodied-energy materials, green architecture, waste-management practices.
Ekanade, Ayanlade & Orimoogunje (2008)	Policy: integrate climate response into national planning; coastal zone management (policy recommendations).
Greenwalt et al. (2021)	Household: raised furniture/doorsteps, temporary barriers, hygiene practices Community: mapping (CMAP), committees, FSM actions Policy: advocacy leading to inclusion in AfDB/WB projects.
Ikechukwu (2015)	Policy: aggressive drainage planning, soft loans for victims, penalties for building on floodplains Household: relocation/asset replacement (coping).
Budnukaeku & Francis (2022)	Building: water-resistant paints/materials, wind-break vegetation, professional construction standards Policy: enforce standards, ban quack builders.
Peace et al. (2019, Earth)	City policy: urgent urban greening/tree planting; land-use management and decongestion.
Peace, Diagi & Suzan (2019, Land Science)	Policy: targeted urban greening, decongestion, integrate HI monitoring into health delivery; priority interventions for hottest land-uses.
Amadi (2025, IJBPA)	Structural: elevated land/buildings, water-repellent finishes, raised electricals Supportive: pumps, barriers, backup power Behavioural: furniture repositioning, savings, desilting.
Chiadikobi et al. (2011)	Policy/planning: map/demarcate flood-prone areas; improve drainage and waste management; field mapping for monitoring.
Ayotamuno (2020)	Policy: improved drainage and enforcement (recommended); Household/community: limited informal coping observed.
Ugwu et al. (2022)	Policy: relocate high-vulnerability properties or adopt protective measures; public education; conform to flood-resistant guidelines.
Amadi (2024, Property Management)	Structural: elevated buildings/land, concrete/block construction, raised sockets Non-structural: repositioning, backup power/storage, gutter clearing; low insurance uptake.
Amadi & Adeniyi (2025)	Measured measures: green landscaping, elevated floors, water-repellent finishes, external barriers, pumps, backup power, savings/insurance, collective action
Akukwe (2014)	Policy/engineering: implement master plan, SuDS, dry dams/levees, enforce demolitions of illegal structures, community drain maintenance.
Wachukwu, Obinna & Weje (2020)	Engineering: concrete drainage, road rehabilitation, demolish/compensate structures on floodplains Community: relief/NGO support; call for integrated structural + non-structural management.

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Appendix 8: Methodological Gaps

Author(s) & Year	Methodological Gaps
Okibe (2025)	No explicit methodological statement; lacks evaluative data on policy/program effectiveness; limited socio-technical data on community decision-making and energy access.
Tari, Brown & Chikagbum (2015)	Sparse local empirical studies/data for Port Harcourt; limited primary data collection on urban poor and climate impacts.
Leka, Gbarabe & Dagogo (2025)	Remote-sensing only (no ground truth); two time-snapshots (Feb 2015 & 2024) only; single-month focus; classification inconsistencies; no socio-economic overlay; no uncertainty quantification.
Okunola, Simatele & Olowoporoku (2022)	Relies on self-reports/Likert scales; no physical/engineering housing measures; binary coding loses nuance; some variables excluded for multicollinearity.
Ekanade, Ayanlade & Orimoogunje (2011)	Coarse climate model resolution; ad-hoc downscaling / interpolation; model uncertainty not fully resolved; no local/household impact data or economic quantification.
Shaibu & Utang (2013)	Very short temporal window (5 days); limited site sample; no wet-season coverage; no health outcome linkage; no housing-stock assessment.
Daminabo & Enwin (2015)	Secondary/descriptive only; no original survey, GIS or hydrological modelling; lacks socio-economic stratification and long-term flood data.
Abimaje & Akingbohungbe (2013)	Review/position piece only—no new empirical data; lacks country-specific lifecycle or cost–benefit analyses for housing interventions.
Ekanade, Ayanlade & Orimoogunje (2008)	Coarse MAGICC-SCENGEN grid; ad-hoc downscaling; interpolation/model uncertainty; no empirical/local household impact data.
Greenwalt et al. (2021)	In-depth but localized (waterfront) samples—limited citywide representativeness; small qualitative samples; attribution challenges (pollution vs. climate); limited instrument calibration; weak evaluation of adaptation effectiveness.
Ikechukwu (2015)	Non-response bias (320/400 valid); cross-sectional self-reports; limited hydrological monitoring; no climate-attribution or citywide representativeness.
Budnukaeku & Francis (2022)	Small convenience sample (55 buildings); perception-based data only; no technical/material testing; questionable climatological figures; no longitudinal tracking.
Peace et al. (2019, Earth)	Snapshot approach (1986/2003/2018); no in-situ validation; 30 m resolution limits microclimate detail; potential seasonal acquisition bias; no socio-economic coupling.
Peace, Diagi & Suzan (2019, Land Science)	Small purposive sample (35 points); single-year data; limited temporal/diurnal resolution; outdoor only (no indoor measures); no health/household linkage.
Amadi (2025, IJBPA)	Quantitative only (no qualitative behavioural probing); purposive area selection (potential selection bias); high tenant skew; no direct measures of mold/thermal outcomes; no causal effectiveness testing.
Chiadikobi et al. (2011)	Limited spatial sampling (4 localities); modest soil sample size; short rainfall window (1998–2007); no hydrodynamic modelling; no quantified socio-economic or building-damage datasets.
Ayotamuno (2020)	Relies on secondary NIMET data; no statistical correlation with specific flood events; lacks socio-spatial flood modelling and community adaptation documentation.
Ugwu et al. (2022)	Cross-sectional snapshot; reliance on OSM (possible inventory errors) and moderate-resolution datasets; subjective AHP weighting; arbitrary buffer choices; no hydrodynamic simulation or household damage data.
Amadi (2024, Property Management)	Quantitative survey only (no in-depth qualitative follow-up); reliance on non-institutional flood delineations; cross-sectional design; no micro CBA or causal effectiveness estimates.
Amadi & Adeniyi (2025)	Dependence on prior studies for flood zoning; RI computed from area aggregates (N=25) limiting statistical power; PCA-derived weights context-specific; cross-sectional proxies (no direct damage/health measures); limited generalisability.
Akukwe (2014)	Perception-based cross-sectional data; no trend analysis; no direct measurement of flood damage or infrastructure capacity; PCA limitations for causality.
Wachukwu, Obinna & Weje (2020)	Subsampled (6/29 communities) and post-event cross-sectional design; recall/self-report and monetization biases; low explanatory power for relocation model; limited qualitative triangulation and no engineering/health metrics.

Appendix 9: Summarized Findings on Climate Change Impact on Housing Quality in Port Harcourt, Rivers State

Author(s) & Year	Findings on Climate Change Impact on Housing Quality
Okibe (2025)	Slum dwellers are highly vulnerable to climate change impacts such as flooding, air pollution, and extreme heat. Poor waste disposal (86% dump waste into rivers) worsens flooding. Lack of tenure and reliance on kerosene/charcoal heighten risks. Grassroots innovations exist but lack institutional support.
Tari, Brown & Chikagbum (2015)	Port Harcourt experiences prolonged rainy seasons (April–Nov, 2,300 mm/year). Areas such as Diobu and D/Line are flood-prone. Rapid population growth (1.9 million, 5.8%/yr) aggravates urban flooding, damaging housing and infrastructure.
Leka, Gbarabe & Dagogo (2025)	Land Surface Temperature increased by +8°C (2015–2024). Impervious surfaces rose from 78% to 93%, linked to Urban Heat Island effects. Loss of vegetation and unplanned urbanization drive rising thermal stress on housing and residents.
Okunola, Simatele & Olowoporoku (2022)	Socioeconomic factors (income, education, housing type, tenure) strongly influence adaptation strategies. Relocation prioritized by households, showing recognition of housing vulnerability. Low resilience among high-density, low-income residents.
Ekanade, Ayanlade & Orimoogunje (2011)	Climate projections show +3–4°C warming and wetter wet seasons/drier dry seasons in Port Harcourt. Sea-level rise and coastal flooding threaten settlements. Housing faces risks of heat stress, flooding, and water-borne diseases.
Shaibu & Utang (2013)	Microclimate differences across land uses show extreme heat stress in commercial/industrial areas (Heat Index up to 40°C+). Housing in dense urban areas suffers more thermal discomfort, increasing risks to occupant health and habitability.
Daminabo & Enwin (2015)	Frequent flooding submerges homes and disrupts neighborhoods. Poorly designed drainages, erosion, and waste blocking drains worsen housing damage. Floods degrade water quality and create sanitation hazards in residential areas.
Abimaje & Akingbohungbe (2013)	Housing contributes significantly to climate change via energy and water use. Housing quality threatened by sea-level rise, heat stress, and disease. Cement-based materials contribute to emissions; adaptive design needed.
Ekanade, Ayanlade & Orimoogunje (2008)	Coastal urban housing in Port Harcourt projected to face higher heat, variable rainfall, and inundation from sea-level rise. Settlements at risk of submergence or chronic flooding; housing stability and safety undermined.
Greenwalt et al. (2021)	Waterfront communities (480,000 people) face persistent flooding (73% of transect sites). Poor drainage and sanitation failures (fecal sludge discharge) compromise housing quality. Residents spend heavily on water despite poor access.
Ikechukwu (2015)	Flooding damages housing stock (cracks, tilting, paint fading, water-logging). Significant income and property losses reported. Flood events last days, disrupting social and economic life. All housing types affected.
Budnukaeku & Francis (2022)	Driving rain defaces buildings (90%), causes dampness (80%), soil creep (80%), and weakens structural strength (50%). Housing maintenance costs increase. Recommends water-resistant materials and climate-aware designs.
Peace et al. (2019, *Earth*)	Land Surface Temperature rose 5.1°C (1986–2018), surpassing comfort thresholds. Urban heat worsens housing habitability, increases cooling demand, and threatens occupant health.
Peace, Diagi & Suzan (2019, *Land Science*)	Heat Index analysis shows late dry season poses highest risk: up to 21% of days in "Danger" category (>41°C). Residential/commercial land uses worst affected. Housing structures intensify exposure due to poor ventilation/materials.
Amadi (2025, IJBPA)	40.8% of households prefer adapting in-place vs relocating. Adaptation includes raised electricals, external barriers, and backup power. Tenant-heavy communities show lower adaptation uptake. Many houses remain at high risk.
Chiadikobi et al. (2011)	Poorly permeable soils, high rainfall, and blocked drainage cause floods up to 150 cm deep, damaging housing. Unplanned urbanization and waste disposal aggravate flood risks. Produced tentative flood risk maps for Port Harcourt.
Ayotamuno (2020)	Climatic variability (rainfall 1,749–2,790 mm/year) drives recurrent flooding. Impacts include destruction of homes, uprooted communities, and increased disease prevalence. Urban sprawl worsens vulnerability of residential areas.
Ugwu et al. (2022)	44,014 properties mapped; 79% moderately flood-vulnerable, 12% highly vulnerable. Properties within 500 m of rivers most at risk. Housing located in low-lying/coarse-textured soil areas highly exposed to flooding.

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Amadi (2024, Property Management)	Housing stock dominated by bungalows with concrete walls but poor finishes (emulsion paint). Flood exposure linked to significant structural (raised electricals, finishes) and non-structural measures. Insurance uptake very low (6.4%).
Amadi & Adeniyi (2025)	Property Resilience Index (RI) shows weak correlation with flood exposure — housing adaptations not scaled to risk. Priority resilience measures include raised electricals, barriers, and elevated land/buildings. Many houses remain maladapted.
Akukwe (2014)	Major flooding drivers: poor/inadequate drainage (42%), heavy rainfall (16%), impervious surfaces (14%), unplanned development (12%). Housing in low-lying floodplains most impacted by structural damage and inundation.
Wachukwu, Obinna & Weje (2020)	2019 flood caused ₦2.51 billion in damages, including cracked walls, floor tile replacement, and household item losses. Residents unwilling to relocate despite severe housing damage due to economic constraints.