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# Susceptibility of Residential Houses to Flood Hazards in Informal Lowly Elevated Coastal Zones in Dar Es Salaam City, Tanzania: The Case of Msasani Bonde la Mpunga

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## ABSTRACT

Human activities and climate change have led to increased precipitation and exacerbated flooding affecting infrastructure, residents, and livelihoods, especially in lowly elevated coastal zones and areas. This study explores the susceptibility of residential houses to flooding in the lowly elevated coastal zone of Msasani Bonde la Mpunga settlement in Dar es Salaam city; and investigates locally adopted adaptation strategies. Tools for data collection included key informant interviews, focus group discussions and building material tests. Quantitative data analysis was conducted using SPSS**,** while qualitative data was analyzed through content analysis. Findings indicated that lowly elevated coastal zones experience severe flood impacts because of their locations. Some houses are of substandard condition while others possess good mechanical properties, yet both are vulnerable to floods. Inappropriate house designs and processing of building materials, lack of technical assistance in building construction, deficient surface drainage, and persistent use of inefficient flood coping measures heighten vulnerability. Adaptation potentials for improving houses' resilience include capacity building in designing and construction of houses as well as integrated flood control. This study contributes knowledge on flood resilience and improved housing to residents in low-lying coastal zones, as well as to technocrats and policy makers. The insights from this case offer scalable implications for housing policy and flood risk management in other lowly elevated coastal zones experiencing comparable socio-environmental conditions.

**Keywords:** Climate change-induced floods, LECZ, houses' vulnerability, adaptation, case study

## INTRODUCTION

Rapid urbanization and subsequent human-environment interactions exacerbate the flooding situations caused by climate change. Across the globe, low-lying coastal zones (LECZ) experience flood risks caused by global warming, sea level rise, storm flow due to climate change and wetland degradation. In 2023, it was projected that, flooding would affect about 900 million people residing in the LECZ (Allen, et al., 2021 and Brakenridge 2021). The informal neighborhoods in LECZs in developing countries are highly exposed to floods (Glavovic, 2022), because of their geographical locations, which are at close proximity to seas, oceans and high-water tables, which are common in densely populated coastal areas (Abadie et al, 2020; Lilai et al, 2016). The vulnerability is worsened by a low adaptive capacity (IPCC, 2023), which could result from lack of resources to cope with and adapt to climate change effects. Despite the planning and execution of some adaptation measures, the adaptation gap exists and continues to grow across sectors and regions. One such region and sector specific areas are the informal settlements in the LECZ of the coastal cities of the tropical regions. This study focuses on flooding challenge, susceptibility of

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buildings in the LECZ to the impacts and adaptation potentials to reduce flood risks.

## BRIEF LITERATURE REVIEW

Urbanisation, climate change and flooding in the lowly elevated coastal zones (LECZ)

The evidence for rapid climate change is compelling. The world is experiencing rising sea levels and temperature, warming of oceans, shrinking of ice sheets in the Himalayas and the Kilimanjaro Mountain, and a glacial retreat and other extreme events (IPCC, 2023; Cardone et al., 2012). The global climate systems indicate an increase in global surface temperatures (IPCC, 2007); floods affecting low-lying coastal areas with large populations, and, an expansion of arid and semi-arid land in Africa by 5 to 8%. Higher risks of flooding in the cities are experienced as a result of climate change and urbanisation (Sun et al, 2021). LECZ are areas typically located less than 10 meters above the sea level and have hydrological connection with the ocean or the sea (Reimann, 2023).

The global review of urban settlements shows that LECZ cover 2% of world's land mass with 10% of world population and 13% of the urban population, residing in such zones (McGranahan et al, 2007). About 8% of Dar es Salaam city lies within the LECZ (Amakrane, 2023), implying that a huge proportion of the city's population is exposed to flood events, given the high concentration of people and assets (Reimann, 2023). The low adaptive capacity of urban communities worsens their vulnerability conditions (IPCC, 2023). Buildings, including residential houses constructed in the LECZ, are among the most vulnerable systems that are affected by climate change-induced floods (Chikodzi, 2022; Cao, 2021). Other urban flood impacts include negative impacts on property values (Blackwell et al, 2024); socio-economic vulnerabilities related to mental health issues, outbreaks of diseases and expenses for house reconstruction and recovery (Kikwasi & Mbuya, 2019); damage to the urban heritage buildings (D'Ayala *et al,* 2020); and damage to property, injury and deaths (Glago, 2021). It is worth noting that, higher risks to floods are experienced in highly densified informal settlements compared with the planned areas because of higher household occupancy rates (Ibrahim *et al,* 2024).

### *Flood actions and vulnerability of buildings*

Depending on intensity and frequency, floods affect buildings by causing damage through erosion (Maranzoni, 2023); soil scour and debris impact (Nadal, 2010); and, and deposition of large amounts owf alluvial material. Other factors influencing the degree of flood damage include the maximum mean flood depth and flow velocity (Santos *et al,* 2024), and, proximity to rivers and catchment areas (D'Ayala *et al,* 2020). Moreover, factors that worsen the vulnerability of building to floods include age of the building and the number of storeys, whereby taller buildings with deeper foundations are generally more stable and less prone to flood damage. Yet, such buildings may be susceptible to differential settlements depending on ground conditions.

The building fabric of external walls are vulnerable to flood situation depending on their water absorption level and the strength to resist lateral forces. Location in respect of site soil properties and drainage is an important factor in determining house vulnerability (D'Ayala *et al,* 2020). More so for LECZ geographic location, building foundation design and materials choices are important. In the context of informal settlements, building exposure and vulnerability to floods risks are affected by whether it is isolated or non-isolated. Isolated buildings are considered as more prone to collapse, while non-isolated buildings have less likelihood to collapse, depending on buildings' densification. In congested buildings settlements, flood water is trapped and difficult to drain away. For LECZ where the physical land slope is gentle, the situation could be worse, even where houses are non-isolated. Moreover, the buildings quality and resilience against floods is controlled by effectiveness of coping strategies; as well as families' socio-economic status and location (Kikwasi & Mbuya, 2019). Particularly for coping strategies to physically enhance housing resistance, *(ibid)* suggest adoption and improvement of coping strategies which show the potential for flood resilience. Generally, the quality of buildings in the flooding informal settlements are commonly weak compared to established standards (Satterthwaite *et al,* 2020).

Resilient construction has recently gained popularity as an integrated approach towards flood risk control. Buildings, civil engineering works and overall built environment have a key role in flood risk management, and more so when these are constructed near flood plains where the need of protecting them is unavoidable (Proverbs *et al,* 2017). Consequently, building construction technology for flooding areas ought to be appropriately developed, particularly in light of climate change projections (Dodman et al, 2022). There is a relatively rich body of knowledge for general building construction techniques for flood safety, explaining various flood resilient constructions, including the preferred flood avoidance strategies. These are mainly town planning legislations, aiming at restricting new development in flood hazardous areas, and natural flood sinks (Proverbs et al, 2017). Avoidance strategies are preferred to fully avoid exposing buildings to floods. Importantly, avoidance appears a more integrated approach as it integrates the building level, plot level and neighbourhood level interventions to prevent floods from reaching buildings, including landscaping design features and surface drainage.

Water exclusion is another strategy where buildings and plots are designed to keep floods away from houses. This includes site assessment, selection of suitable materials, effective drainage and building design with proper placement of electrical and plumbing systems. Water inclusion strategies are designed on assumptions that flood water will enter the building. However, due to complexities around various cities and site characteristics, such techniques may be applied with limitations on their performance. Some complexities in the LECZ include house quality, households' socio-economic status, site conditions and building construction knowledge and practices. Other factors depend on the hydrological characteristics, including the depth of floods, the velocity and whether the floods are slow or fast in onset (Proverbs *et al,* 2017).

Building materials specifications and characteristics determine the quality and vulnerability of buildings to flood impacts (Maskell *et al,* 2018). Different building materials possess different levels of resistance to water exposure. Despite bricks and blocks being porous materials, they can properly resist water instruction with efficient construction knowledge. However, in conditions of prolonged moisture, they can absorb water leading to weakening and cracking (Ojedele *et al,* 2024**).** Cement-sand block wall tested for strength against lateral load, showed minimal deflection and ability to withstand flood levels experienced, despite being of slightly lower quality standard (Kikwasi & Mbuya, 2019). Building materials specifications in determining a house vulnerability to floods is explained in several other factors including durability and resistance to degradation and structural integrity during and after flooding (Pratiwi, 2024). Roof drainage design affects floods at building and neighbourhood levels. Gutters and proper flashing provision control rainwater flow off the roof, to safe deposits, to specifically keep the foundations and exterior from flood exposure. Though indirectly, rain water collected from roofs and not safely collected and transferred, can pour randomly around houses and the neighbourhood, adding to floods.

Additionally, surface drainage is an important design feature for flood resilience at building and neighbourhood context (Sohn *et al,* 2020). Particularly for the LECZ, the land physical structure is a fundamental factor in hydrological research (Shah and Ai, 2024), to determine storm water flow and drainage. Some studies show that low-lying settlements in LECZ in developing countries are not resilient to floods. Victor *et al.* (2023) indicate that 100% of houses lacked the architectural technology to withstand floods in low lying shores, adding that, the applied flood coping strategies were inadequate to withstand floods.

### *The Risk Management Theory: Understanding Vulnerability of Buildings to Floods*

The assessment of building vulnerability to floods applies the Risk Management Theory (RMT), emphasizing construction practices which reduce flood risks. The RMT recognizes inherent risks in house development process based on their nature, while underscoring the importance of understanding risks in specific environment where they may happen. Contextualization explores the unique characteristics of individual construction sites, highlighting the need to analyze site-specific features during the design and building construction processes. This approach aligns with construction management principles, notably, those related to design processes and the knowledge and skills required for effective house delivery in flood threatened areas. Lenhardt (2024) notes that coastal cities face high exposure to extreme weather events, with urban poor populations most at risk due to poor housing quality. Kajumulo (2024) notes inadequate skills among building artisans which contribute to challenges in designing for floods. Specific areas where skill deficiencies are observed include leadership, cost management, project schedule management, and addressing specific site conditions. In line with the RMT, the concept of Low Impact Development (LID) further supports flood resilience at the neighbourhood level. LID promotes technologies such as restoring natural hydrological functions and incorporating permeable surfaces, to improve urban water management (Ambily et al., 2024). Water management is important for enhancing building site exposure to floods, which affect the site-specific conditions.

### *Conceptualizing Flood Vulnerability to Buildings*

The conceptual framework that guided vulnerability assessment of buildings included the LID concept, the RMT and construction management concepts, as presented in Figure 1. The RMT offers the main construct analysis (evaluation of flood risks' potential impact), and risk planning (measures to reduce flood risks). The conceptual framework informs how risk management process can influence the performance metrics in a construction project, which are based on the Construction Management Theory (Windapo, 2013). The metrics include: the climate, where flood effects are transferred to the affected area; technological factors, i.e., flood actions in respect of buildings' performance; ***socio-***

***economic conditions***, influencing houses' quality based on financial requirements; and, the ***capacity of institutions*** for housing delivery, including urban development control and building codes for flood prone areas. The metrics relevance is in advancing an understanding of the construction project challenges which are not easily comprehended by general project management theories. According to Radosavljevic and Bennet, 2012), most construction procedures for buildings and infrastructures can deal with normal conditions, but when an external driver such as climate and geology behave unpredictably, these designs are often caught out unprepared.

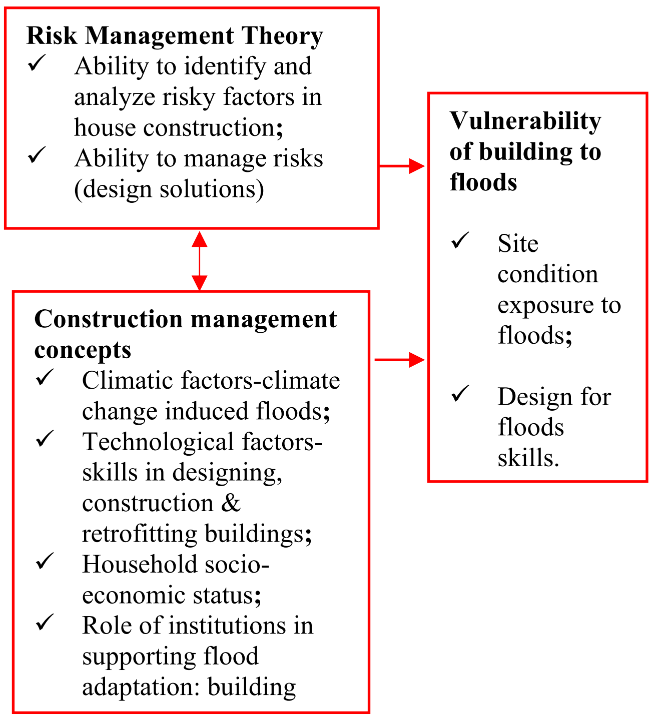


**Figure 1: Conceptual Framework for assessing vulnerability of floods to buildings in the LECZ**

## METHODOLOGY

This study employed a case study design to comprehensively investigate the extent of buildings' vulnerability to floods, the effectiveness of the adaptation practices and how the building structures can be made flood resilient. The case study design was developed from ground-level knowledge abstracted from communities experiencing floods over the years. The selection of MBM case study area was based on flood proneness, proximity to the ocean and elevation above sea level. Figure 2 shows the location map of the case study area (MBM) in Dar es Salaam city. The area was roughly demarcated, purposively aiming at households with different income levels for in-depth interviews. Houses were then randomly selected, to ensure sufficient representation. The unit of analysis for the study were the houses for which the quality of construction materials, the construction process and the homeowners' understanding on vulnerability factors were explored. The population size (N) was 2010 houses, from which 239 houses were sampled. The sample was calculated using equation (1).

$$N = \frac{N.z^2.p.(1-p)}{E^2.(N-1)+z^2.\,p.(1-p)} ------------------- (1)$$

where, **n**=sample size; **N**=population size; **z**=z-score for the 90% confidence level; **p**=estimated proportion of the population; E=margin of error (5%).

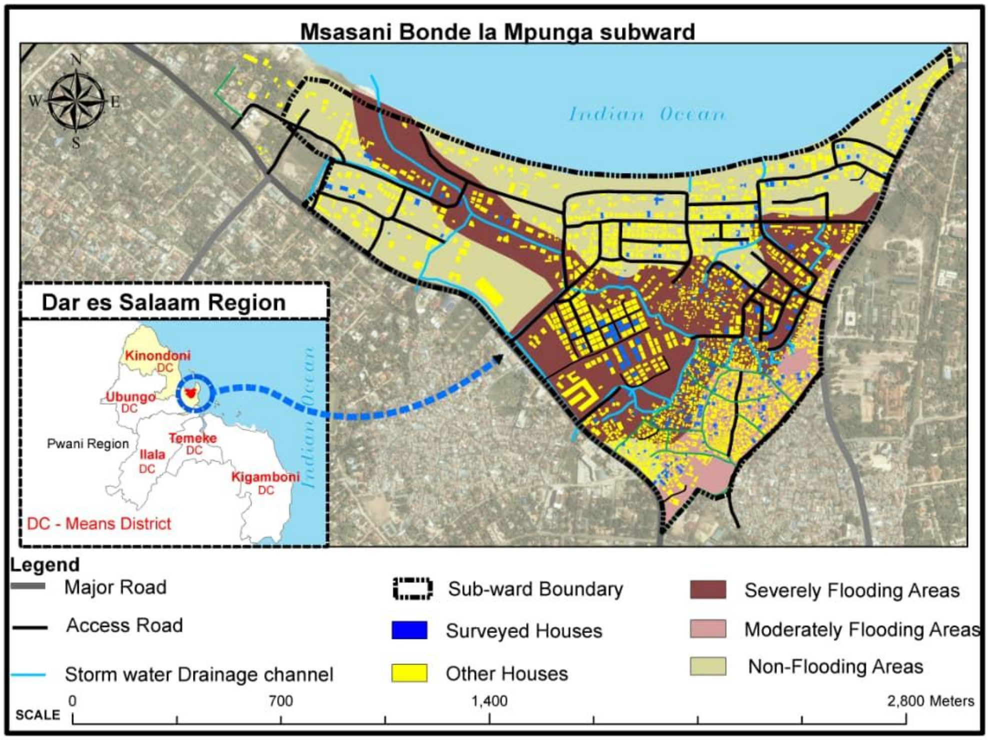


**Figure 2: Location of the case study area (MBM), flood exposure and surveyed houses**

In order to narrow the margin of error, and practical considerations to consider potential non-response, a sample of 252 was selected. The first step in selection of the unit of analysis was based on a rapid appraisal of the building types according to building materials in the case study area. Most houses were of cement-sand block walls while other walling materials formed a negligible proportion as shown in Table 1.

**Table 1: Building materials types in MBM sub-ward in Dar es Salaam, Tanzania**

| Category | Material/Type | Number of Houses (%) |
|---|---|---|
| **Foundation** | Block walls on compacted soil | 42 (16%) |
| | Strip foundation with block wall | 200 (80%) |
| | Timber poles driven into ground | 6 (2%) |
| | Unknown | 8 (3%) |
| **Walls** | Cement sand block wall | 246 (97%) |
| | Mud and pole | 6 (3%) |
| **Roof Type** | Flat roof with reinforced concrete (RC) slab | 6 (3%) |
| | Corrugated iron sheets (CIS), mono/double pitch | 197 (78%) |

| Category | Material/Type | Number of Houses (%) |
|---|---|---|
| | Corrugated iron sheets (CIS), flat | 49 (19%) |
| **Wall Finishing** | Mud paste | 2 (1%) |
| | Non-plastered | 158 (63%) |
| | Plastered | 66 (26%) |
| | Plastered and painted | 26 (10%) |
| **Roof Drainage** | Presence of roof drainage system | 88 (35%) |
| | Absence of roof gutters | 164 (65%) |

Qualitative information offered the ability to capture the real-life experience in a LECZ context. Semi-structured interviews guided comprehensive, qualitative data collection, including exploration of emerging areas of relevance, that the researcher had not initially anticipated. Listening, recording and transcribing stories from house owners and flood victims provided valuable insights on residential choices; understanding of the relationship between climate change and floods; the buildings' construction processes; how building structures are impacted based on their quality; and, efficiency of the applied flood adaptation measures. Qualitative data collection involved interviews with key informants and focus group discussions. Important consideration for selecting participants in data collection was identifying respondents who were well informed about data and information being sought. In addition to enabling access to critical information, this tool allows knowledge co-creation between the researcher and respondents (Buys et al, 2022). Observations and photographs complemented interview data offering visual analysis of buildings' condition; coping measures used; and surface drainage systems. Table 2 provide summary of key informants, which were relevant for this study.

**Table 2:** Key informants' details

| Informant profile | No. | Core area of contribution |
|---|---|---|
| Engineer, Kinondoni Municipal Council | 1 | Building inspections & issuance of building permits |
| Town Planner, Kinondoni Municipal Council | 1 | Urban planning standards & development in flooding areas |
| Architect, Kinondoni Municipal Council | 1 | Inspection and approval of building designs |
| Building artisans, MBM & vicinity | 2 | Construction of houses in the case study area |
| Drainage Engineer, DCC | 1 | Storm water drainage within neighbourhoods in the city |
| Influential people in the community | 4 | Women, home owners, settlement transformation through housing development, flood adaptation interventions |
| Chairperson & Executive Officer, MBM subward | 2 | Flood and illegal constructions reporting in MBM |
| Environmental committee member, MBM | 1 | Environmental governance & flood incidences report |
| Gender & Climate Change Tanzania Coalition | 1 | Climate change awareness on vulnerable groups |
| Inhabitants for more than a decade | | Personal experiences with flooding impacts on buildings |
| Vice President's Office-Department of Environment | 1 | Climate adaptation planning & climate urban resilience |
| Prime Minister's Office-Disaster Management Department | 1 | Disaster preparedness & coordination of relief |
| Tanzania Meteorological Authority | 1 | Climate projections in the country |
| Environmental Officer, Dar es Salaam City | 1 | Environmental information at city level |
| Public Health Officer, Dar es Salaam City | | Public health information from flood vulnerable houses |
| National Environmental Management Council | 1 | Environmental advice to the governments & communities |

Quantitative data were used to examine building characteristics, flood extent, and construction material quality. Structured questionnaires were administered to collect data. These aimed to capture the quality of selected house components and the construction process, including involvement of qualified building technicians and socioeconomic status of households, as both dictate house quality through technical expertise and financial capacity. Other information included flood coping strategies employed by different homeowners.

Laboratory tests were used to ascertain the condition of selected building materials. This involved testing sampled materials used for exterior walls which are typically used for house construction in the study area. Fabrication of cement-sand blocks for testing purposes replicated the typical construction practices of house developers in MBM. To ensure that blocks made reflect real conditions as in the case study area, cement and sand used were sourced directly from suppliers commonly used by local house developers, to match the specific types commonly used in MBM. Similarly, the mix ratios for cement and sand mixes were the same mix designs typically applied in the case study area. The quality of external walls was tested for strength against lateral loading, representing floods. The focus was to replicate the materials quality and processes as built on the site. The tests included compressive tests on blocks, water absorption test and the gross density test. Compressive strength test was conducted for block samples made onsite as typically used in house construction in MBM. The block-making process was carried out following identical procedures used by house developers, including casting, compacting and curing, to ensure that the resulting samples are representative of the materials and techniques employed in construction in the case study area. Blocks were labelled and cured before carrying out the compression test. Water absorption tests were carried out to assess the rate of water absorption and its effect on block wall strength, as block walls are porous materials. Wet block weights and corresponding compressive strengths were measured at different time intervals (12, 24, 36, 48 and 72 hours). This represented mechanical behaviour of the blocks under different flood durations. The gross density test was aimed at determining the strength of blocks in respect of adequacy of block compaction. For the gross density, block samples cast based on typical site conditions were measured and recorded. The density of each block was calculated from these results. The aim was to compare the results with the established standards for the building materials, which were envisaged to indicate the level of vulnerability of such materials to floods.

Mixed data analysis was employed using triangulation to complement information obtained from both methods to avoid biasness and increase validity and reliability of the result. Quantitative data were analysed using the Statistical Package for Social Sciences (SPSS) software, where results were numerically and graphically presented using the MS-excel, and further analysis. In the analysis, the data collected were pulled to generate the realistic representation including the factors contributing to buildings' vulnerability under flooding conditions. Qualitative data were coded and collated based on thematic similarities and relationships. Emerging patterns were identified to form similar themes, each of which were discussed, describing their meanings. This information was merged with the analysis of results from quantitative data, to draw conclusions.

## RESULTS AND DISCUSSION

Findings from collected data and the corresponding discussions are presented for building components quality (foundation and walls). Additionally, household income, engagement of professional building services, effectiveness of flood coping strategies and other attributes which may affect the quality of buildings and adaptability to floods are presented, as these factors collectively relate to the household's capacity to provide structurally sound housing**.**

**Building materials quality in MBM**

***Foundations***

The houses were assessed for foundation quality as it contributes to the ability to withstand building loads, both self-weight and external forces such as lateral flood pressures. Findings show that, majority of the houses (81.6%) in MBM, are constructed on concrete foundations. Others, (18.4%), are built using block walls erected direct on compacted trenches, without the use of concrete. In respect of presence and quality of foundation, relationships were examined to reflect households' incomes. The prevalence of concrete foundation use varied across income groups earned monthly as follows: 13.3% in households earning less than USD 125.00; 23.3% in the USD 125.00-225.00 range; 100% in the USD 225.00-325.00; 6.67% in the USD 325.00-425.00 range; and 28.3% among households earning above 425.00.

A regression analysis was conducted to determine the relationship between constructing houses with foundation with household income. The analysis showed an insignificant relationship between households' income levels and building houses with foundations, with a value of 0.2, at a significant level of 0.01. This indicates a non-linear relationship between household income and the use of concrete foundation. The peak adoption of concrete foundation occurred in the mid-income households, while the lower and higher income households presented low adoption. This analysis suggests that, beyond income, factors such as construction knowledge and skills significantly influence the provision of concrete foundations in buildings. This aligns well with the conceptualisation of the buildings' vulnerability to floods, where construction skills are identified as a key variable (Kajumulo, 2024; Windapo, 2013).

Building construction knowledge becomes critical, as observed by some house developers. A middle-income house owner with good awareness on climate change effects and flood risks observed:

> *In line with building design and construction skills in flooding areas, the technicians advised against using reinforced concrete strip foundation due to their likelihood to increase soil moisture retention, leading to house settlement. Instead, a block wall from the excavated trench base was recommended to facilitate water seepage. This would reduce moisture intrusion through subfloors and external plinths during floods. Despite this design, some houses remain susceptible to flood impacts.*

Persistent flood setting in some areas of MBM after rainy seasons, correspond to findings by Cissé and Sèye (2015). The use of perforated foundation materials and overall sub-structure facilitates drainage, reducing water accumulation and additional hydrostatic pressure around foundations. Mukhamejanova et al. (2023) observe that the strength of the hollow foundation with perforation ought to be higher than the solid foundation, whilst the settlement for the hollow foundation slightly exceeded that of the solid foundation due to additional compaction of the filling materials. Generally, the analysis of findings highlights limitations in design adaptation or implementation, and the role of context-specific construction decisions. These findings corroborate with findings in a study by Coulbourne (2010) who observed that the damage to coastal buildings was contributed by insufficient information by the engineers in foundations design. This indicates that, the local building technicians possess valuable construction skills, although they may require technical improvements. These findings imply that, integrating and improving such context specific skills into house construction could enhance resilience of buildings in the flood prone LECZ.

***External walls: blocks and mortar***

*Blocks compression test*

The results of block compression test indicated that the average compressive strength was below the minimum standard requirements (3.5-7.0N/ $mm^2$). The average strength was 2.7 $N/mm^2$. These results indicate that in real world condition, the current flood did not exceed the capacity of the entire structure. Nevertheless, the situation does not justify the use of blocks which are substandard, especially with uncertainty of the future flood events (Figure 3).

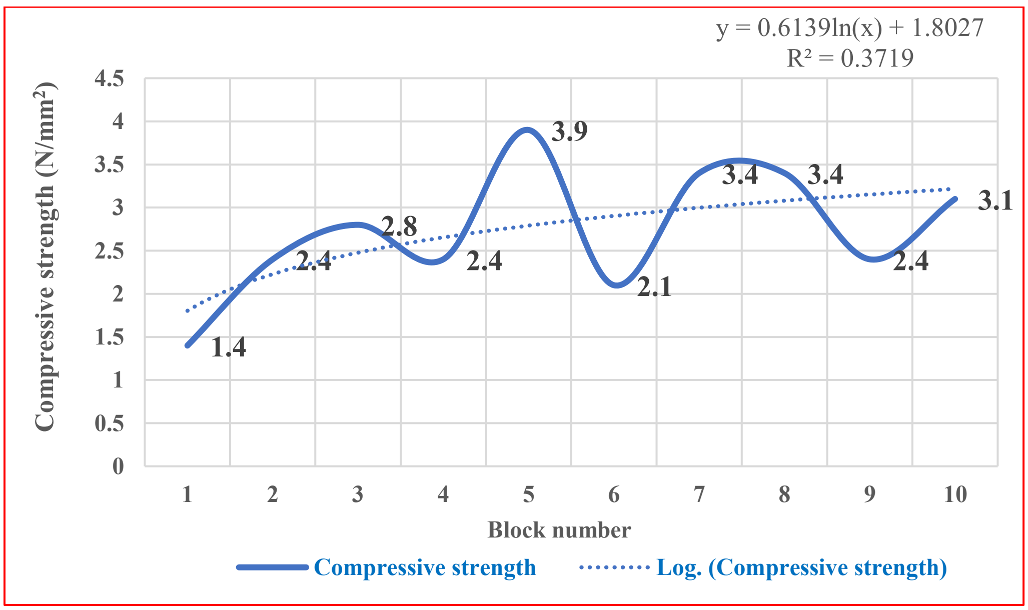


**Figure 3: Compressive strength tests for sampled blocks**

The variations (x) represent different factors affecting block strength and block wall quality, including the amount of cement, the quality of compaction, the curing time, and the curing frequency. The correlation coefficient of 37.19% indicates a moderate to weak relationship, suggesting presence of other variables affecting block compressive strength. Although the average strength exceeds the standard requirements, the observed variability is likely attributable to critical factors such as the accuracy of the mix ratios, material quality, and block-making practices, all of which reflect workmanship and quality control skills, represented by the Log. Compressive curve. This curve shows how the compressive strength change with workmanship and quality control skills.

*Water absorption test*

Test results on water absorption revealed that blocks reached maximum absorption at 39% of their dry weight after 36 hours of soaking. Beyond this point, up to 72 hours, the blocks reached saturation point, indicating they could no longer absorb additional water. This suggests that walls constructed with these blocks will absorb water up to this limit, after which excess water flows over the surface. At this post-saturation state, block strength declined to approximately 52.7% of the original value, dropping from 1.1 N/mm$^2$ to 0.58N/mm$^2$ (Figure 4). Thus, when subjected to flood conditions, typical block wall with these properties exhibit a maximum compressive strength of 0.58N/mm$^2$. Ojedele et al. (2024) reported a similar observation noting a reduction in strength due to prolonged moisture exposure.

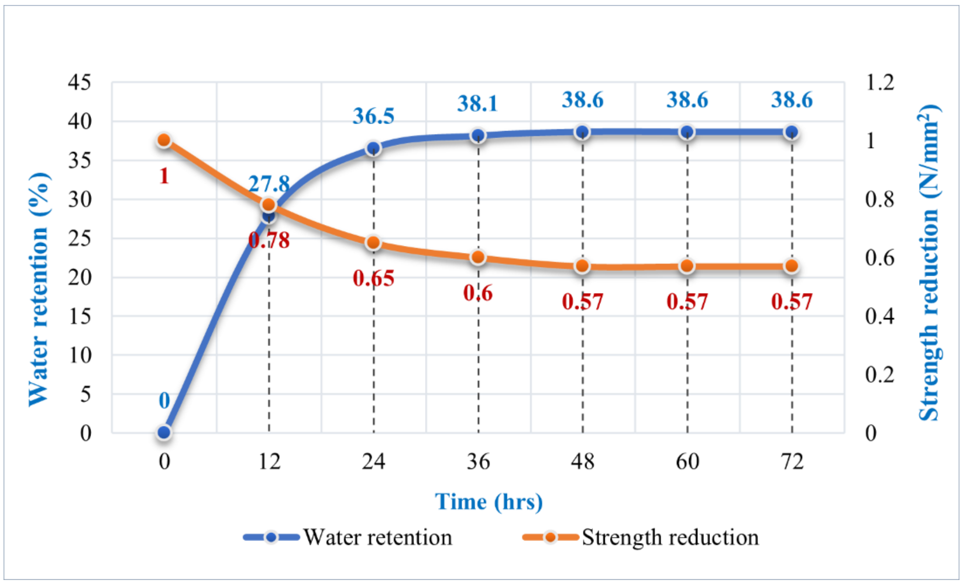


**Figure 4: Blocks' test-water retention and respective strength reduction**

*Gross Density*

The result of the average density for 10 blocks was 1480 kg/m$^3$, which was compared with the recommended standard of 1920kg/m$^3$, the minimum limit stipulated in British Standard, BS 2028(7) which guide construction activities. This indicated that the block falls below substandard blocks' density threshold, which correlates with reduced block strength. These results represent many houses built in the low-income and in high-income areas of MBM.

**Table 3:** Gross densities for sampled blocks in MBM sub-ward

| Block Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gross density (kg/m$^3$) | 1550 | 1360 | 1360 | 1430 | 1480 | 1370 | 1590 | 1510 | 1670 | 1470 |

An assessment of wall quality in relation to family income revealed that both low-and high-income families had homes with varying wall strengths (Figure 5). However, high-income households more commonly had better-quality block walls. Three key factors are clarified by this variation: (1) some homeowners intentionally built with good quality blocks to protect houses from flood damage; (2) others relied on pre-made blocks assumed to be high quality, though this did not apply in all instances; and (3) some could not afford blocks cast to recommended standards by using improper mix ratios, leading to reduced strength, e. g., using one bag of cement for 60 blocks instead of the recommended 30. Mortar quality, was also critical to wall strength and flood resistance. The standard mix ratio of 1:4 (cement: sand), ensures effective bonding and load distribution. Findings showed 88.1% of buildings used good-quality mortar, with higher usage among moderate to high income households.

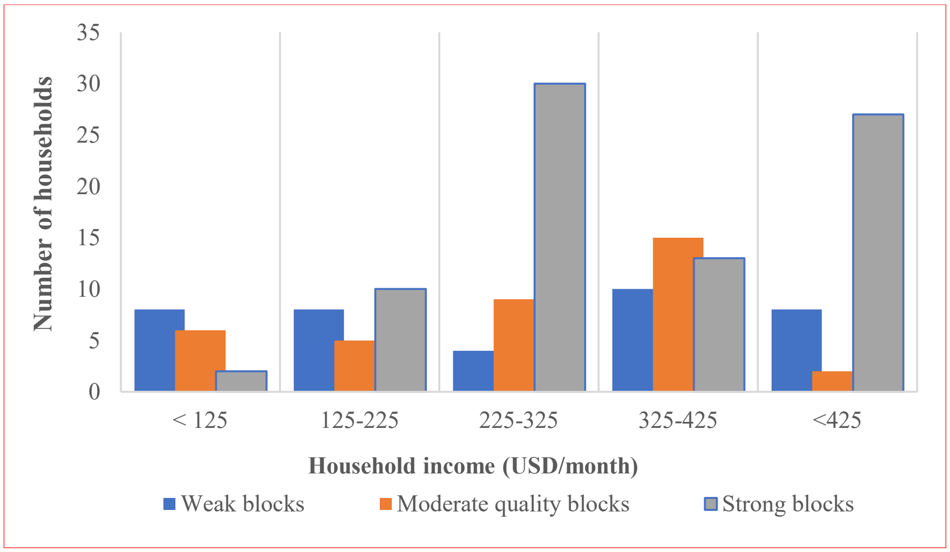


**Figure 5: Quality of external wall versus household income**

The findings suggest a positive correlation between household income and the quality of construction materials, particularly block strength, with higher-income families more likely to use standard-compliant blocks that enhance structural integrity and flood resilience. This indicates that economic capacity significantly influences homeowners' ability to invest in durable building materials, thereby affecting housing safety and performance. Further implication is on lower-income households being more likely to use substandard blocks, facing increased vulnerability to floods due to reduced wall strength.

***Engagement of professional services in house construction***

The engagement of building technicians in house construction was analyzed in relation to household income. The number of households employing technicians was found to increase with income level: 5 households in the lowest income group, 7 earning USD 125-225, 12 earning USD 225-325, 15 earning USD 325-425, and 12 in the highest income bracket (above USD 425).

Analysis of findings shows three distinct patterns regarding labour engagement and quality of house construction. Firstly, the use of registered contractors was limited, with only one low-income household and three high-income household employing them. Secondly, the do-it-yourself (DIY) approach involving primarily family labour, was adopted by 3 of the 58 respondents, all from the southeastern part of MBM, a low-income area. Idowu *et al* (2024) acknowledge the association of employing building technicians with delivery of good quality houses. As such, the DIY cost-saving measure can substantially lead to substandard construction. Although the proportion of households employing the DIY approach was small (5.2%), it is a significant proportion that should not be overlooked. If this trend becomes normalized, the number of low-income households relying on DIY construction may increase, leading to proliferation of substandard and flood vulnerable houses, and intensifying flood risk in low-income communities. This aligns with Lenhardt (2024), who notes that unplanned urbanization can intensify inequality, deepening urban poverty. Thirdly, for house construction arrangement, typically involve house developers verbally contracting the technicians to review building specifications, after which the technicians propose labor and material costs. Construction begins following verbal negotiation and agreement, building incrementally, logically to meet financial requirements faced by most house developers. This method was used by both low- and high-income households, particularly those anticipating flood risks.

Key informant interviews with selected low-income households who employed registered contractors are represented by house owners, named A and B:

Quoting respondent, A:

> *'I hired the services of a building technician trusting that the house would be safe from floods, also considering that a house is a lifetime investment. Good quality construction materials were procured for the house. However, my home is constantly exposed and isolated by floods. Moreover, during and long after the rainy seasons, water discharge indoors from sub-floors*.

Quoting respondent B:

> *Despite developing a small, two-bedroom house, I applied for a loan to supplement savings made from my medium scale business along Msasani Road. I hired the services of a building technician believing that the house would be safe from floods. He advised raising the house plinth as an adaptation strategy to floods. It works; I have been safe for the past three flooding seasons.*

Findings show that limited design and construction skills among building technicians in flood-prone LECZ significantly contribute to flood susceptibility and increased post-occupation maintenance costs. This aligns with Alabi and Fapohunda (2021), who link high maintenance expenses to poor workmanship. While the quality of structural elements like foundations and walls is important, the technical expertise of building technicians plays a more critical role in achieving flood-resilient housing. This observation corroborates what is reported in a study by Kajumulo (2024) where site condition challenges negatively affected construction projects. This links well with the Risk Management Theory provisions, supporting that, the site-specific challenges can be effectively addressed where the capacity of building technicians is adequate.

In MBM, a significant number of houses lack rainfall gutters, an essential roof drainage system. Without gutters, rainwater falls directly off the roof, impacting external walls and the plinth area, causing deterioration of wall finishes, foundation erosion, and moisture ingress, altogether compromising structural integrity. This issue is particularly critical in the southwestern part of MBM, where housing density is high and spacing between buildings can be as narrow as one to two feet. In such environments, uncontrolled roof runoff not only affects the individual building but also disperses storm water around the plot, into adjacent plots, compounding the surface water accumulation across the neighborhood. This contributes to localized flooding events, even in the absence of broader flood events. When numerous houses lack functional roof drainage systems such as the case of MBM, the cumulative impact significantly increases surface water accumulation, foundation weakening, and neighborhood-wide flooding. As such, the mismanagement of roof runoff transforms to bigger flood risks. These findings underscore the importance of incorporating rainwater management solutions, specifically roof gutters, for retrofitting existing houses and for new house constructions is essential. This is important for individual house and wider densely populated LECZ settlement protection from floods. Skilled building technicians are key actors to implementing these adaptation interventions.

***Flood coping strategies for buildings***

Coping strategies are important because they contribute to buildings' resistance against floods. Strategies for flood coping are planned for flood exclusion, to prevent floods from entering into houses, while ensuring continued functioning of the houses. Raising houses above expected flood levels was employed by 12% of households, based on the assumption that peak floods remain below plinth height. However, this strategy was rarely applied to main buildings for cost saving; instead, 42% of households in severely affected areas raised pit latrines only. Plinth elevation for overall housing structure through landfill was used by 4% of respondents, primarily wealthier commercial property owners, from its expensive nature. This technique involves increasing ground height slightly above regular flood levels. Barrier walls at house entrances were a common strategy among 34% of low-income households in the densely populated southwest MBM, although floods frequently exceeded these barriers. In the same areas, another coping strategy was the use of sandbags, half-filled and placed lengthwise around the buildings at the wall bases to absorb shock and reduce debris damage. In contrast, in the higher-income areas, characterised by larger plot sizes, 9% have constructed stormwater drainage systems around plots. These house owners pump floods outside their properties, disposing them immediately at the boundaries of the fences.

Plinth elevation was more commonly applied to external pit latrines than to main houses, driven by communities' financial ability. Economic constraints also limit the adoption of this strategy for entire houses, as the cost is unaffordable for most residents. The sandbag technique offers limited flood protection; where plinths exist, sandbags do not reach sufficient height, and where absent, they typically measure just 100 mm high from the ground level. Although residents recognize that floodwaters exceed sandbag height, they use them to reduce flow velocity and wall erosion. Nevertheless, sandbags do not guarantee flood prevention, an observation supported by Victor et al. (2023). In contrast, affluent households that pump water from their premises poorly dispose flood waters to adjacent areas, exacerbating localized flooding. Moreover, practiced by the few high-income households, raising house plinths through landfilling the construction sites showed a potential for houses' flood resilience. However, its effectiveness is limited by inadequate technical knowledge among building technicians regarding plot level design and the floods transmitted to adjacent plots and broader settlement hydrology movements.

The findings reveal that flood coping strategies employed by residents of Msasani Bonde la Mpunga (MBM) are largely ineffective because, despite these efforts, houses remain vulnerable, resulting in continued exposure of houses to flood risks. Among the strategies, raising the house plinth showed effectiveness; however, its success relies on the technical competence of builders, particularly in determining average flood depths and constructing appropriate foundations, walls and roof drainage systems. Despite the flood coping strategies being limited in the informal, densely built areas, the analysis indicates that many of the current approaches result in increased long-term vulnerability, rather than effective adaptation. As such, emphasis should focus on retrofitting the existing houses to enhance flood resistance, including waterproofing foundations and external walls, using flood-resistant materials, and fixing or restoring surface drainage systems. Recent development in policy acknowledges informal settlements as legal and eligible for upgrading rather than demolition (URT, 2012).

Consequently, enhancing flood resilience through structural retrofitting is critical in such contexts. For newly built houses, adaptation should focus on building site grading, drainage redesign, effective roof drainage systems, and the use of resilient construction materials. The proposed measures are scalable and offer a sustainable pathway toward building adaptation to floods, particularly those in the LECZ. The findings also challenge prevailing debates that informal settlements are inherently uninhabitable due to flood risk.

## CONCLUSION

This study concludes that houses built in the Msasani Bonde la Mpunga MBM sub ward are highly vulnerable to flood hazards, primarily due to their location in the low-lying coastal areas, and by being informally developed. The vulnerability is exacerbated by lack of technical competency in building design and construction in flood threatened areas. The technical capacity gap is also evident through ineffective flood coping strategies that are used. The findings underscore the critical need to strengthen the technical capacity of building professionals to address the specific challenges present in flood-prone site conditions within LECZ. Traditional construction practices, which often prioritize material properties are insufficient in such contexts. Additionally, effective flood-resilient construction requires not only formal technical knowledge but also the integration of local, experience-based insights possessed by community-based technicians. Moreover, the selection and implementation of flood coping strategies must be carefully evaluated to prevent maladaptive outcomes that may increase long-term vulnerability.

Findings have important implications for both policy and practice, offering transferable insights from Msasani Bonde la Mpunga (MBM) that can inform flood resilience strategies in other low-elevation coastal zones (LECZs) facing similar challenges. The findings offer important implications for both policy and practice, offering scalable insights from Msasani Bonde la Mpunga (MBM) which can inform flood adaptation strategies in other low-elevated coastal zones (LECZs) facing similar flood and house quality challenges. The vulnerability of the houses, particularly in the informal settlements, underscores the need for scalable, context specific adaptation measures. Central to this is the integration of targeted skills building for building technicians into the frameworks for flood resilient building construction.

Strengthening technical capacity in building site assessment, design and construction techniques is essential for improving the adaptive capacity of houses in urban systems.

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