Assessment of adaptation strategies to flooding: A comparative study between informal settlements of Keko Machungwa in Dar es Salaam, Tanzania and Sangkrah in Surakarta, Indonesia

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A large number of informal settlements in developing countries are located in high risk areas (low-lying lands and on river banks). This situation is caused by poverty and the inability of authorities to supply planned plots for building to meet demands of the growing urban populations. Informal settlements have, in turn, triggered disaster risks, flooding being just one of them. As a way of reducing impacts of flooding, residents in informal settlements have resorted to the use of structural adaptation strategies. Despite these efforts, the vulnerability of people and properties in informal settlements is increasing. This article aimed to provide an answer as to why this is the case, by assessing and comparing the technical suitability of adaptation strategies to flooding in the informal settlements of Sangkrah and Keko Machungwa and recommending measures for improvement. Household interviews, physical observation (visual inspections of signs of damage and deterioration), measurements of height of physical adaptation strategies, mapping, photographing, and in-depth interviews were the key methods employed. Generally, in both cases, it was determined that flood mitigation and risk minimisation measures through structural adaptation strategies were hardly achieved at the household level, as adaptation strategies were constructed with little or no attention to acceptable technical considerations. However, when levels of compliance to technical considerations in the construction of houses were compared between the two cases, they were found to be slightly higher in Sangkrah than in Keko Machungwa. Residents in Sangkrah demonstrated a slight difference, especially in the use of reinforced concrete (4.3%) for constructing a building's foundation, as well as in the use of ceramics (72.9%) to construct the floor. In order to deliver technically suitable adaptation strategies, efforts need to be directed toward: regulating and controlling the construction of structures for adaptation, enhancing individual coping capacity, deployment of a workforce trained in disaster risk and management and enforcement of relevant urban planning and environmental management laws in managing risky areas.

Introduction

Recent studies have shown that cities of developing countries have, since the 1960s, faced a high rate of urbanisation (UN-Habitat 2009, 2010). In this case, Tanzanian and Indonesian cities are good examples. In Tanzania, estimates for the year 2010 indicated that the urban population proportion was at 26.4% and this figure is expected to rise to 31.8% and 38.7% in the years 2020 and 2030, respectively (UN-Habitat 2008). The 2010 census showed that Indonesia's total population has increased from 203.5 million to 237.6 million in the last 10 years; whereas, the urban population grew from 85.2 million to 118.3 million during the same period (Firman 2012).

This rapid population growth is a challenge in developing countries. In many countries in Asia and sub-Saharan Africa, for example, rapid population growth is taking place in the context of low economic growth and financial deficit. The deficit tends to impede efforts of providing planned plots for housing and basic services (UN-Habitat 2009). This condition has significantly contributed to the growth of informal settlements. The situation is worse in capital cities; for instance, 60% of inhabitants in Jakarta, Indonesia lived in informal settlements (commonly known as urban *kampungs* in Bahasa, Indonesia) by 2006 (UN-Habitat 2006). The situation is even more dire in the city of Dar es Salaam, Tanzania, where 80% of all residential houses are found in informal settlements.

Available research evidence shows that informal settlements are often built in high risk areas such as river banks, deep gullies and in floodplains that are particularly susceptible to extreme weather conditions (Kombe 1995; UN-Habitat 2009). In addition, the informal settlements are being confronted by uncoordinated urban development (Dubovyk, Šliužas & Flacke 2010; Islam *et al.* 2006; UN-Habitat 2009). The majority of poor people in developing countries live in informal settlements (UN-Habitat 2009) and thus are faced with many challenges including flooding (Kyessi & Tumpale 2013). In an effort to cope with flooding, informal settlement dwellers apply various adaptation strategies. Despite these efforts, it is worth investigating reasons for increased vulnerability of people and properties in informal settlements in the search for pragmatic intervention measures.

Findings from previous studies that address adaptation strategies have focused on aspects including, (1) mapping of flood-prone areas, (2) assessment of damages to structures (Kreibich & Thieken 2008; Smith 1994), (3) forms of adaptation strategies, (4) availability of, and access to, resources as a way of understanding what facilitates or inhibits adaptation capacity (Eakin & Lemos 2006), (5) economic impacts of flooding (Meyer, Priest & Kuhlicke 2012) and (6) flood modelling (Marfai 2003). Yet, in these studies, the technical aspect of adaptation strategies is hardly addressed. Consequently, there exists a void of analyses on the technical aspect of adaptation strategies applied to flooding in informal settlements. The research literature reports shortcomings of different adaptation strategies used for mitigating floods. The shortcomings discussed in this article have been found to aggravate flood hazards (Yin & Li 2001). This underlies the rationale for conducting this research, which studied two urban informal settlements, namely Sangkrah in Surakarta, Indonesia and Keko Machungwa in Dar es Salaam, Tanzania. The aim of this research was to assess and compare the technical suitability of adaptation strategies in the two case studies and recommend measures to reduce the vulnerability of the two communities.

Objectives

The main objective of the study was to assess the technical suitability of adaptation strategies toward flooding in Sangkrah and Keko Machungwa's informal settlements, with a view to improve adaptation strategies at the household level. Studying technical suitability was central for ensuring that adaptation strategies were reliable in protecting people and properties against flooding. However, before assessing the technical suitability of adaptation strategies, it was important to explore available adaptation strategies. Another aim was to enhance awareness amongst residents, public organisations and the governments of both countries in terms of viable options for mitigating flood-related risks and improving adaptation strategies in urban informal settlements.

Literature review

An overview of technical suitability factors

In the context of this study, the term 'technical suitability' means a situation where an adaptation strategy (structures) and buildings constructed in flood-prone areas meet formal engineering criteria (Federal Emergency Management Agency [FEMA] 2008). Engineering criteria include: use of experts or professionals in designing and construction of structures, use of building materials resistant to flood damage, use of standard measurements (e.g. height in relation to base flood elevation [BFE]) and proper maintenance of structures, amongst others. Adhering to these technical suitability factors is essential when applying adaptation structures for flood mitigation. It is especially important for saving the lives and properties of local community residents who have settled in flood-prone informal settlements.

Where buildings are situated in a floodplain, careful design of buildings and flood protection structures has the potential to reduce the vulnerability of flood damage and, therefore, reduce the flood risk (Jha, Bloch & Lamond 2012). Many structures fail to withstand adverse flood action because of insufficient attention when designing and implementing structures (Ikoma 1992). To avoid reconstruction cost, time and ineffective situations, the use of experts is strongly recommended for designing and constructing flood control measures (Ikoma 1992).

Flood water discharge can affect structures and buildings located in flood-prone areas; therefore, care must be taken to choose the best building materials (UN International Strategy for Disaster Reduction, UN Development Programme & German Technical Cooperation 2008). Best materials in flood-prone areas are referred to as flood damage-resistant materials and are defined by FEMA (2008:2) as, 'any building content capable of withstanding direct and prolonged contact with flood waters without sustaining significant damage'. Therefore, when houses and adaptation structures need to be built in flood-prone locations, design must consider the use of construction materials that are resistant to locally experienced hazards.

Construction of structures in areas susceptible to extreme flooding need to adhere to recommended engineering standards. According to FEMA (2008), one of these standards is measurements. In the context of this study, one of the key measurements examined was BFE, which is the estimated height to which flood waters are anticipated to reach in a particular flood-prone area. The BFEs are based on data gathered from the topography of the area, as well as floodplain effects from prior flooding. For example, a retaining wall should be one foot (approx. 0.3 m) higher than the BFE in order to provide the maximum amount of protection against flood waters (FEMA 2008).

Maintenance is a disaster prevention strategy, as it expresses the intention to minimise and/or avoid potential adverse impacts through action taken in advance (UN International Strategy for Disaster Reduction 2009). In order to minimise the need for recovery and reconstruction, proper maintenance of structures before the occurrence of a disaster is crucial (Kates *et al.* 2006; Wu & Zuo 2010). Some of the actions that can be taken include clearing of solid waste and repairing damaged structures.

This research assessed the technical suitability of adaptation strategies with a view towards contributing improvement in the quality of adaptation strategies at household level. In this regard, this research attempted to answer the following questions: Are there adaptation strategies at household level? Are adaptation strategies employed by household technically suitable? What factors contribute to negligence of technical suitability factors? How do the adaptation strategies in the two cases compare in terms of relevance to flood risk reduction? How might the existing adaptation strategies in flood-prone urban informal settlements be improved?

Previous studies on flooding in informal settlements

Flooding, to a large extent, has gained much attention from different scholars; therefore, there is a wide range of literature on the flood hazard. Febrianti (2010) and Sakijege, Lupala and Sheuya (2012) are examples of recent studies on flooding and adaptation strategies in the informal settlements of Sangkrah and Keko Machungwa, respectively. In Surakarta City, Febrianti (2010) identified physical coping strategies such as raising the home's foundation, building emergency living quarters on the roof top and using sand bags. Community social and cultural coping strategies included: working together for cleaning the surroundings, sharing food and distributing information about flooding, amongst others. Febrianti (2010) concluded that the applied adaptation strategies were ineffective for minimising flood risk. Therefore, there is a need to support the efforts of the local community and the local Government toward reducing the flood risk.

Likewise, according to Sakijege *et al.* (2012), Keko Machungwa's informal settlement has been frequently affected by flooding. To minimise flood risk, communities and local authorities have employed various adaptation strategies which range from structural to non-structural strategies. However, Sakijege *et al.* (2012) also concluded that the long-term goal of flood risk minimisation was only partially achieved. Little support from the municipal council and the community's perception that flooding was a temporary problem were the reasons for that failure. Finally, for better ways to improve the adaptation strategies, Sakijege *et al.* (2012) proposed that a comprehensive study needed to be conducted on the technical suitability of the coping strategies at household level.

Other similar studies conducted in Surakarta and Dar es Salaam included research by Hidayat (2009), Lerise and Malele (2005), Šliužas (2004) and Zein (2010). All observed that flooding was a serious problem and that most adaptation strategies applied were ineffective toward minimising flooding and its associated impacts.

Research method and design

Procedure

The study primarily used qualitative rather than quantitative assessment methods; these consisted of household interviews, physical observations (including visual inspections of signs of damage and deterioration, e.g. cracks, dampness, etc.), mapping, photographing and in-depth interviews with selected respondents. Household interviews were held with flood victims to identify available adaptation strategies. The interviews were also meant to establish whether or not technical factors (in terms of use of experts, flood damage-resistant materials, standard measurements and proper maintenance) were incorporated in the design, implementation and management of flood protection structures.

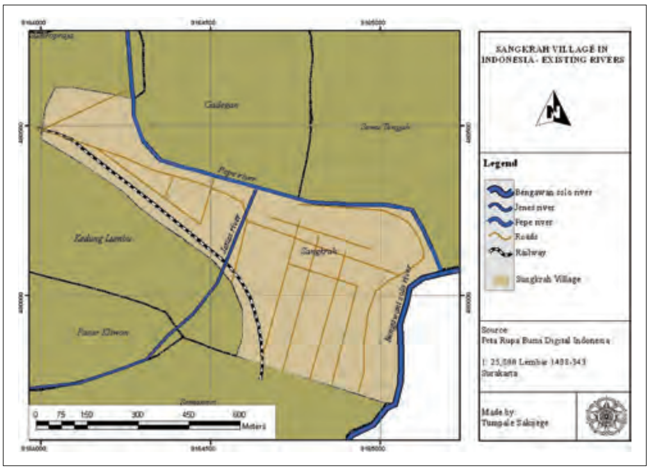
The only quantitative assessment used was for taking simple measurements; results were then correlated with the BFE. Measurements of structural height of flood control structures were performed for retaining walls, plinths, raised pit-latrines, raised foundations and raised stairs. Because informal settlements have been frequently affected by flooding, one would have expected guidelines to be in place for flood deterrence that specified building materials, BFEs, building designs and so forth. Unfortunately, there were no national guidelines in Tanzania or Indonesia on the design and material requirements for buildings located in flood hazard areas and, as such, FEMA (2008) guidelines were used. However, it was acknowledged that FEMA guidelines might not be conducive for application in Indonesia and Tanzania considering the lower level of technical development compared to the USA.

Setting

Five criteria were developed in order to identify and select cases that were suitable for conducting the study; these were, (1) existence of informal housing development, (2) a settlement traversed by a river and thus susceptible to riverine flooding, (3) a settlement that experienced the problem of intensified flooding over time, (4) residents who demonstrated effective responses for containing flooding and (5) a settlement which needed critical intervention in terms of flood control measures. All informal settlements in Surakarta and Dar es Salaam were subjected to evaluation based on the aforementioned criteria and Sangkrah and Keko Machungwa informal settlements were chosen as potential in-depth case studies.

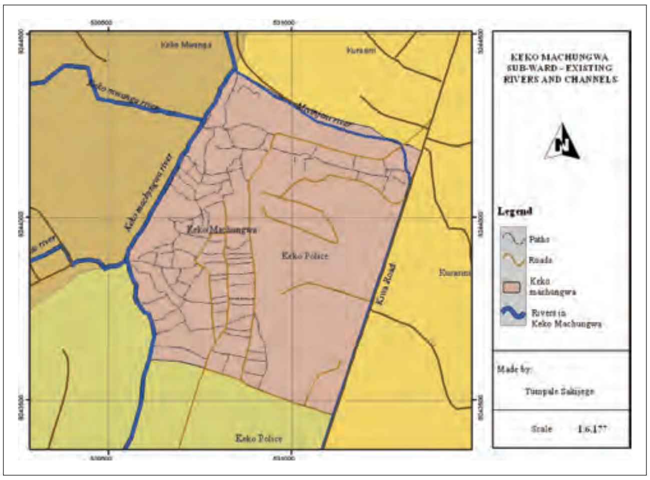
The word *sangkrah* in the Javanese language means any kind of materials deposited in the local depression, usually rubbish or garbage and might also include wood transported by water, usually during flood events. Therefore, geomorphologically, *sangkrah* literally means 'floodplain'. Sangkrah is located in Surakarta City, within the Bengawan Solo River basin (SMERU Research Institute 2011), which is the longest and the largest river basin on Java Island, draining approximately 16 000 km^2 of the island (Takeuchi, Jayawardena & Takahasi 1995). The Sangkrah informal settlement is traversed by the Bengawan Solo River (Figure 1) and, thus, is located within the river's floodplain, making it a suitable study site.

On the other hand, Keko Machungwa is located in Dar es Salaam City in Tanzania. It is located within a valley of a seasonal stream (Figure 2) and is characterised as a wetland



Source: Adapted from Febrianti, F., 2010, 'Flood risk perception and coping mechanism of a local community: A case study in part of Surakarta city, Central Java Province, Indonesia', MSc thesis, The International Institute of Geo-Science and Earth Observation, Enschede

FIGURE 1: Sangkrah informal settlement traversed by Bengawan Solo River, Central Java, Indonesia.



Source: Map created by the authors for the purposes of this study

FIGURE 2: Keko Machungwa informal settlement traversed by seasonal streams in Dar es Salaam, Tanzania.

receiving storm water drainage from different elevated parts, eventually discharging into the Indian Ocean. The 1968 *Dar es Salaam master plan* (United Republic of Tanzania 1968) designated Keko Machungwa as a hazardous area in the sense that it was frequently waterlogged and, hence, not suitable for a human settlement development (Sakijege *et al.* 2012). It is important to note that informal settlement began at Keko Machungwa in 1960 – 8 years before the *Dar es Salaam master plan* became effective. Despite zoning of the area as hazardous, informal settlement development has continued. This situation has led to a concentration of buildings, which, in turn, increases the amount of surface water runoff and, consequently, increases the potential for flooding and associated impacts.

Owing to their location (in low-lying areas) and the nature of development taking place (informal), the two selected study areas are, therefore, affected by riverine and urban or local flooding, respectively.

Sampling

This study employed qualitative procedures for establishing the appropriate number of households to be interviewed. The researcher determined that an appropriate sample size of 70 households in each location would be more than adequate for achieving the goals of the study. The researcher also applied a quantitative procedure involving a mathematical formula by Baradyana and Ame (2005) to establish whether or not the determined sample size was adequate and representative.

Results

Magnitude of flooding

As stated above, Sangkrah lies within the Bengawan Solo River basin, which frequently experiences flooding caused by long periods of rains. The precipitation potential in the basin is therefore high and, when coupled with an inadequate drainage system, increases the risk of flooding. The Bengawan Solo River basin has a precipitation potential of 2100 mm per year, of which close to 1040 mm remains as overland flow. This has been one of the causes of floods in the basin, in general, and in the Sangkrah informal settlement in particular. The most severe floods recorded in the Bengawan Solo River basin occurred in 1966 and 2007, with the 1966 flood inundating an area of 142 000 ha (Network of Asian River Basin Organizations 2007) and the 2007 flood causing estimated damages of $200 million (Hidayat 2009). The Sangkrah informal settlement was one of the villages affected by both of those floods. During extreme rainfall, water depth can reach 4 m in Sangkrah; in these cases, the existing flood control infrastructures become overloaded and fail to protect people and properties. Survey results from this study showed that about 1415 houses in Sangkrah are located within the flood-prone area and, thus, are frequently affected.

Keko Machungwa has been affected by frequent flooding because of its location in a river valley and the absence of robust flood control infrastructures. The worst flooding experienced in Keko Machungwa and Dar es Salaam City, in general, was the flood event of December 2011, in which Government authorities (United Republic of Tanzania [URT] 2012) confirmed deaths of 40 people. It was also reported that over 1000 families were displaced and their livelihoods impacted during the 2011 floods (URT 2012). Keko Machungwa was amongst the Dar es Salaam settlements most affected by floods in 2011 and, in some cases, the settlement experienced the effects from flooding even if it did not rain in that area. Such flooding was caused by surface runoff from surrounding elevated areas. In extreme events, water depth normally reaches 1.5 m. As a result, surface runoff takes time to dry because of the nature of the soil which does not allow smooth infiltration. The findings of this study revealed that about 150 houses in the settlement are frequently affected by flooding.

Available adaptation strategies

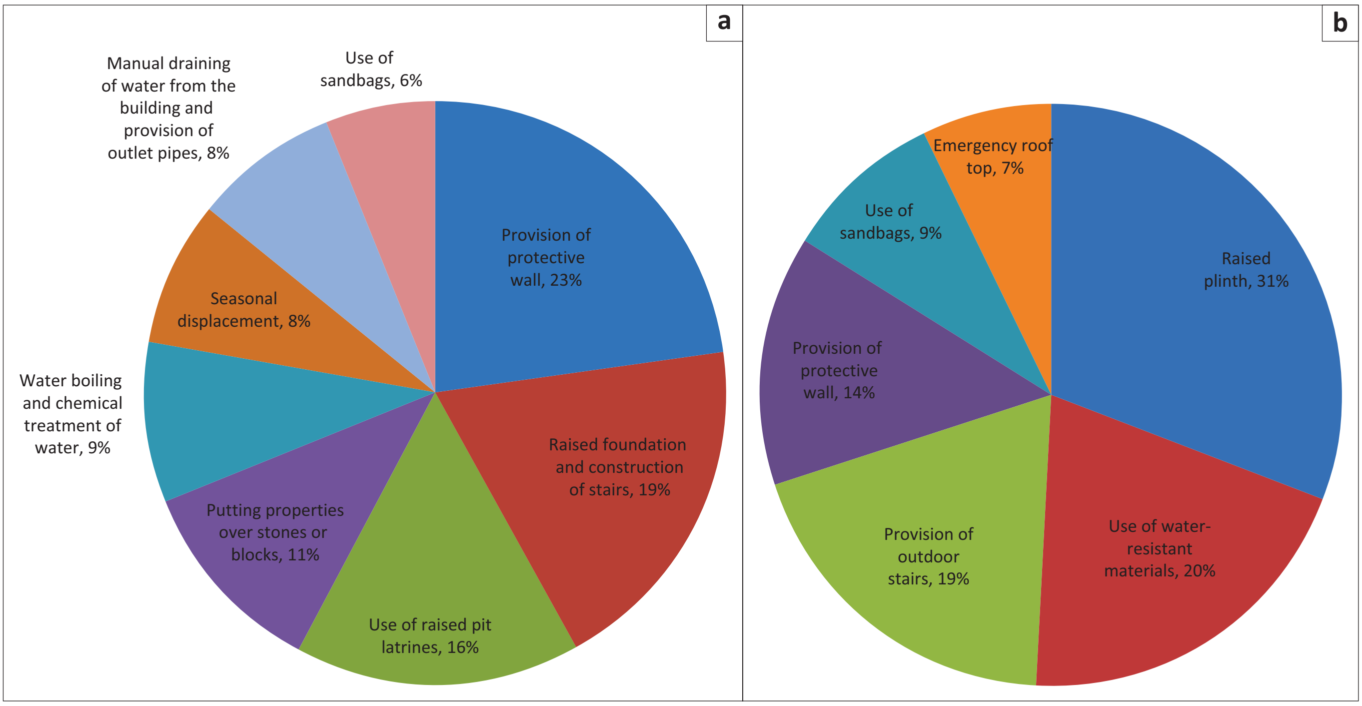
Presently, as the problem of flooding continues to increase, flood victims choose to apply various adaptation strategies to minimise flood impact. Across the two cases, it was revealed that the adaptation strategies ranged from structural to non-structural strategies. The adaptation strategies applied by flood victims are summarised in Figure 3.

Lack of expert input for design and construction stages

The main finding in both cases was observation of the limited use of experts for structural design, choice of building materials and construction techniques for specific adaptation strategies. Financial constraints were reported as a major factor that contributed to this situation. Instead of using experts, interviewed households reported that they used untrained local artisans, which was linked to the fact that their skills were relatively inexpensive and easily available within informal settlements. This was revealed by 82% and 89% of the interviewees in Sangkrah and Keko Machungwa settlements, respectively. One of the interviewees in Sangkrah reported that, 'I can't afford the cost of hiring an engineer, I use our boys. They are so helpful'. Unfortunately, observations also revealed that flood protection structures and sometimes even entire buildings were destroyed by floods (Figure 4).

Use of standard measurements for adaptation strategies

According to the flood histories of the two settlements, during extreme flood events, flood water normally reaches a depth of 4.0 m in Sangkrah and 1.5 m in Keko Machungwa. According to FEMA (2008), the water depth of the previous flood is considered the BFE and, thus, any structure for flood mitigation must be constructed one foot (approx. 0.3 m) higher than the BFE. Any flood protection structure constructed below the required BFE will not deter floods and, thus, is considered technically not suitable. Quantitative measurements from the two cases showed that all protective structures were constructed below the BFE (Figure 5). For example, the height of retaining walls and raised stairs in Sangkrah were lower than BFE by 2.8 m and 3.8 m,

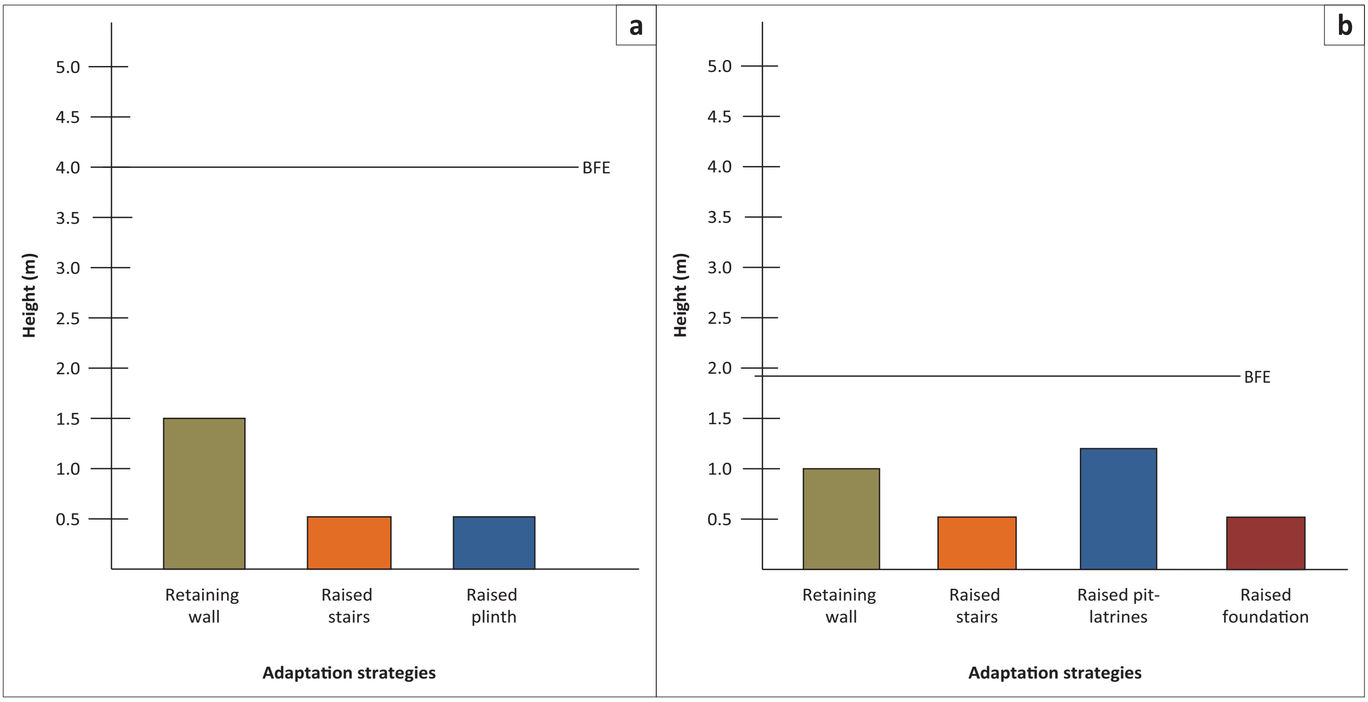


Source: Authors' own construction

FIGURE 3: Adaptation strategies at household level for, (a) Keko Machungwa and (b) Sangkrah informal settlements.

Source: Photographed by T. Sakijege

FIGURE 4: Flood damage to properties as seen by, (a) collapsed protective wall in Keko Machungwa and (b) destroyed house in Sangkrah after flooding (c) same house before flooding.



Source: Authors' own construction
BFE, base flood elevation.

FIGURE 5: Comparison of the height of flood protection structures relative to base flood elevation in, (a) Sangkrah and (b) Keko Machungwa informal settlements.

respectively. In Keko Machungwa, the average height of the retaining walls and raised stairs were lower than the BFE by 0.8 m and 1.3 m, respectively.

Use of materials resistant to flood damage

It was observed that there were variations in terms of building materials used to construct various parts (foundation, floor, wall and roof) of buildings which impacted adaptation strategies. For example, 88.6% of interviewees in Sangkrah reported that building materials used for construction of house foundations consisted of soil bricks with cement mortar. On the other hand, 78.8% of interviewees reported that materials widely used to build house foundations in Keko Machungwa were sand and cement blocks. In both cases, the same construction materials used to build home foundations were also chosen by residents for flood protection structures. According to FEMA (2008), all these materials are vulnerable to floods when there is a prolonged flood event.

Another observed area of variation from FEMA guidelines (2008) was technical suitability of materials used to construct home floors in the two cases. It was observed in Sangkrah that the majority of interviewees (72.9%) constructed their home flooring using ceramic materials, whereas in Keko Machungwa, about 81.4% stated that most were built with sand and cement flooring materials (see Table 1). This was a deviation from the recommended use of waterproof cement and ceramic materials in the construction of home flooring by FEMA (2008). Inadequately constructed sand and cement floors in Keko Machungwa increased the vulnerability of buildings as it allowed underground water to percolate into houses. This infiltration raised water depths and dampness levels in walls (Figure 6). About 52.9% of houses in Keko Machungwa were reported to be affected by water infiltration problems.

The use of ceramic flooring (72.9%, see Table 1) as observed in Sangkrah may be considered to be reasonable as far as technical requirements were concerned; however, it did not necessarily mean that buildings with such floors were resistant to flooding. Buildings should be constructed using appropriate materials, as well as taking into consideration all other necessary technical aspects. This was not the case in Sangkrah, where it was learned that, although most homes had ceramic floors, their walls were made of soil bricks and mud mortar which were not water-resistant building materials. Walls built with such materials are generally weak and not able to resist the hydrodynamic forces of flood waters. The wall-building materials used in the two cases did not conform to FEMA's guidelines, as Table 1 shows. However, overall, Sangkrah households did comply more with FEMA (2008) guidelines than Keko Machungwa, as Table 1 illustrates, in that 4.3% of Sangkrah interviewees used reinforced concrete to construct the foundations of their buildings, whilst 72.9% used ceramics to construct floors. According to FEMA (2008), reinforced concrete and ceramic are flood-resistant materials.

Proper maintenance

When maintenance of flood protection structures was examined, both cases revealed the lack of maintenance as reported by 72% and 79% of interviewees in Sangkrah and Keko Machungwa, respectively. This practice also indicated the disregard of factors meant to deliver technically suitable

TABLE 1: Assessment of building materials in relation to flood resistance.

Building material category	Building material type	Technical suitability			Percentage of respondents	
		Resistant†	Resistant to some extent‡	Not resistant§	Sangkrah	Keko Machungwa
Foundation material	Reinforced concrete	•	-	-	4.30	-
	Sand cement blocks	-	•	-	7.10	78.60
	Soil brick with cement mortar	-	•	-	88.60	21.40
	Total	**-**	**-**	**-**	**100**	**100**
Floor material	Ceramic floor	•	-	-	72.90	-
	Sand cement floor	-	•	-	14.30	81.40
	Soil or sand	-	-	•	12.80	18.60
	Total	**-**	**-**	**-**	**100**	**100**
Wall material	Brick (clay) with cement mortar	-	•	-	22.80	24.30
	Brick (sand and cement)	-	•	-	4.30	65.70
	Brick (clay) with mud mortar	-	•	-	31.40	-
	Mixed (clay and wood)	-	•	-	15.70	10.00
	Untreated bamboo	-	-	•	14.30	-
	Untreated wood	-	-	•	8.60	-
	Zinc	-	•	-	2.90	-
	Total	**-**	**-**	**-**	**100**	**100**
Roof material	Asbestos	•	-	-	52.80	-
	Clay tile	•	-	-	31.10	-
	Zinc	-	•	-	16.10	-
	Iron sheet	-	•	-	-	100
	Total	**-**	**-**	**-**	**100**	**100**

Source: Data collected for the purposes of this study; technical suitability determinants adapted from Federal Emergency Management Agency, 2008, 'Flood damage-resistant materials requirements for buildings located in special flood hazard areas in accordance with the National Flood Insurance Program', *Technical Bulletin* 2, FEMA, Washington, DC

†, The materials are resistant to floodwater damage from wetting and drying; they can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants.

‡, These materials can withstand flood water for a certain period of time. A prolonged flood event will render these materials vulnerable.

§, These materials are not resistant to flooding because they do not take into account the effects of long-duration exposure to floodwaters or contaminants carried by floodwaters.

Source: Photographed by T. Sakijege

FIGURE 6: Dampness and waterlogging inside a house in Keko Machungwa resulting from underground water percolation.

adaptation strategies. Thus, the absence of maintenance has led to weakening of flood protection structures, rendering them vulnerable to failure during floods.

Discussion

In both cases, flooding was perceived as the most frequent event consequently causing disastrous effects. There were also perceptions that climate change and uncontrolled development will increase risk from flooding in flood-prone areas in the future. Thus, it was expected that such awareness on the severity of flooding, as well as the perception of increased vulnerability, would inspire adoption of effective and efficient adaptation strategies. Unfortunately, this was not found in either area; instead, adopted strategies were of a lower standard than perceived risk. About 61% and 68% of interviewees in Sangkrah and Keko Machungwa, respectively, had the perception that returns from 'proactive' risk reduction were not obvious, which was why they subscribed to the culture of 'reactive' risk reduction, that is, providing support when the problem had already occurred. These perceptions have contributed significantly to increased levels of vulnerability to flood impacts of residents in the case study areas.

Findings in the two case studies suggest that decisions made by flood victims to employ adaptation strategies of certain standards depend on their level of income and the construction cost. With limited financial resources, priority is normally given to other 'more immediate and important' expenditures, such as food, education and health; thus, there is little consideration for investing in flood control infrastructure. In that case, financial capacity plays an important role in the choices and applications by individuals of particular adaptation strategies.

In Indonesia and Tanzania there were shortages of trained workers on disaster issues; thus, issues associated with disaster management most likely were inadequately administered (Kassenga *et al.* 2008; US Agency for International Development 2007). This was substantiated by the fact that local bodies or committees for disaster management were not adequately equipped to deal with disaster issues. For the case of Indonesia, local bodies for disaster management did not exist in some of the cities (e.g. Surakarta), as provided for in the *Law Concerning Disaster Management* (Law No. 24 of 2007) (Republic of Indonesia 2004). This impeded efforts to address effectively disaster issues at lower levels. In Tanzania, there were disaster management committees at almost all levels starting from the national to the local. However, members of the disaster management committees were politicians or Government employees who were not necessarily conversant with disaster risk management issues (Kassenga *et al.* 2008). Therefore, an adequately trained workforce on disaster issues was insufficient. Consequently, flood victims did not get sufficient help and guidance in dealing with flooding situations nor did they receive public guidance and education for application of effective adaptation strategies.

The findings of this study provide adequate evidence that communities in the two flood-prone informal settlements were well-informed about flooding and its associated risks. However, the level of awareness did not tally with the robustness of adaptation strategies applied. Two opposite views were evident with regard to availability of adaptation strategies. Firstly, it was revealed that every interviewed household across the two cases applied a certain adaptation strategy to minimise flood impacts. Thus, in terms of initiative, flood victims in both cases have attempted to apply certain flood adaptation strategies. Secondly, the technical suitability of these adaptation strategies was compromised as a result of inadequate consideration of the factors meant to deliver technically suitable adaptation strategies. This was evident in the 2007 and 2011 flood events in Sangkrah and Keko Machungwa, respectively. During those flood events, the impact was heavily felt in the two cases, despite the existence and use of certain adaptation strategies.

The disregard of technical considerations in terms of expert knowledge, use of water-resistant construction materials, appropriate dimensions and maintenance have rendered most of the available adaptation strategies dysfunctional and, consequently, technically unsuitable for resisting flood impacts. This finding confirmed the argument of Ikoma (1992) that structures fail to withstand adverse flood actions because of insufficient attention when designing and implementing. Findings of this study were similar to the findings of De Risi *et al.* (2013), who observed that informal settlements were particularly vulnerable to flood events because of both their generally poor quality of construction and high population density.

As revealed by the present study, financial constraints, application of 'reactive' as opposed to 'proactive' disaster risk reduction approaches and shortage of staff in dealing with disaster issues were the major factors contributing to the disregard of technical suitability factors by residents in flood-prone informal settlements. The observation that most of the applied adaptation strategies at the household level were ineffective in minimising flood risks was similar to that of Febrianti (2010). However, Febrianti (2010) did not identify factors that caused adaptation strategies to be ineffective.

Recommendations

As mentioned earlier, engineering aspects of structural adaptation strategies were not covered in this study. Therefore, it would be worthwhile to assess the robustness of the flood protection devices by conducting tests on characteristics of building materials and ratios used amongst other engineering aspects. Furthermore, efforts to deliver technically suitable adaptation strategies would require addressing various key issues, as elaborated hereunder.

Firstly, although the study has shown that the adaptation strategies at household level were technically unsuitable, the fact cannot be denied that households in flood-prone informal settlements did initiate efforts to establish adaptation strategies to reduce the impacts of flooding. As a way forward, the initiatives at household level need to be enhanced. In order to fully transform the reactive mindset into one that reduces risk and prevents impacts, continuous investment is required to enhance awareness. Government, in collaboration with other key stakeholders such as non-governmental organisations and development partners, can accomplish this through establishment of social learning process.

Secondly, the construction of structural adaptation strategies should be regulated and controlled to follow current procedures for infrastructure construction. That is, following a procedure that involves, (1) application of building permits to relevant authorities, (2) scrutiny of design drawings, (3) site inspections by qualified and authorised personnel, (4) issuing of construction consent and (5) monitoring the construction process to ensure that the prerequisite technical aspects are considered and implemented. In addition, there is a need to strengthen workforces through training of competent workforces so as to increase the level of awareness on disaster reduction issues.

Thirdly, existing urban land development control should be enforced to prevent human settlements development and related investments in flood-prone areas. In this case, urban planning laws, regulations and guidelines could be used to direct wise use of flood-prone areas. For reducing vulnerability of properties and people living in risk areas, there is a need to embed management of risky areas embedded into disaster reduction and environmental management laws. In this case, provisions of the *Law Concerning Disaster Management* (Law No. 24 of 2004) (Republic of Indonesia 2004) and *Law Concerning Spatial Management* (Law No. 26 of 2007) (Republic of Indonesia 2004) and the *Environmental Management Act, 2004* (Act No. 20 of 2004) (United Republic of Tanzania 2004) should be effectively enforced by relevant authorities.

Conclusion

A combination of two factors, namely location in high risk areas and uncoordinated development, makes informal settlement dwellers and their properties susceptible to flooding and its associated risks. This study found that residents in the two case study areas were aware of the flooding problem in their settlements and, thus, they applied various adaptation strategies. However, assessment of particular adaptation strategies at the household level concluded that these were technically unsuitable for effective minimisation of flood impacts.

The study revealed several major factors that were a threat to the application of technically suitable adaptation strategies, including: financial constraints, employment of 'reactive' approaches to disaster management and an inadequately trained disaster reduction workforce.

Some limitations were evident in the reported study. Firstly, the primary author's specialisation called for employing a qualitative (inductive) methodology, including only summary or descriptive statistics, rather than a quantitative (deductive) empirical approach based on hypothesis testing and generalisation to theory. However, depending on the intent of the researcher, both approaches are viable ways to conduct research. In this case, the qualitative approach allowed for assessments based on visual inspections, observations, measurement taking and identification of construction materials used in relation to their resistance to flooding. Secondly, this research did not allow for assessment based on engineering aspects, such as ratios of construction materials used, quality of the adaptation strategies and soil type, as these are methods of analysis outside the areas of specialisation of the main author.

Despite these limitations, the study for which this article was prepared achieved its objectives by revealing the realities of adaptation strategies employed by the household in informal settlements as far as flood risk minimisation is concerned. In addition, it created awareness amongst the residents, public organisations, the Government and other key stakeholders involved in flood risk reduction about factors that cause residents in the flood-prone informal settlements to disregard technical suitability factors when devising adaptation measures.

This awareness was created through discussions with respondents on the technical suitability aspects of various adaptation strategies and how they could be used to improve their functionality.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

T.S. (Gadjah Mada University) was responsible for field data collection and article writing, whilst J.S. (Gadjah Mada University), M.A.M. (Gadjah Mada University), G.R.K (Ardhi University) and S.E.K. (Ardhi University) were the supervisors, advisors and contributors.

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