ANTHROPOGENIC DRIVERS OF FLOODSANDHOUSEHOLD ADAPTATIONSACCROSS THE COASTAL WETLAND AREAS OF LIMBE AND DOUALA IV MUNICIPALITIES, CAMEROON

Abstract

Many coastal urban areas are experiencing impacts of accelerated and episodic flooding on the built environment and people's livelihoods and quality of life. Floods do not just occur, as certain factors (human and natural) and triggering mechanisms (engineering and non-engineering) continuously operate in synergy to either limit or accelerate flooding in the study areas. This work aims at examining the anthropogenic factors contributing to increasing floods across the coastal areas of Limbe and Douala IV Municipalities-Cameroon. Data for this study was generated from primary and the secondary sources. A total of 390 questionnaires were administered using stratified random samplingas well as 5 interviews. Data was entered into EpiData Version 3.1 and analyzed using IBM Statistical Package for Social Science (SPSS) version26. Digital Elevation Map of the study areas was drawn showing levels of vulnerability to flood hazards in the study area. Findings revealed that areas between 1-5m a.s.l such as Clark's Quarter, Down Beach, Mabanda and Ndobo witnessed severe flooding. There was a statistically significant relationship between poor drainage facilities, haphazard settlement construction, blockage of drains by refuge and severe coastal flooding with probabilities values of (0.00582**, 0.0597* and 0.0888*) respectively. Construction on raised foundation (p = 0.0439**), raising bed higher above the floor (p = 0.0370**), placement of valuable items above the floor (p = 0.0613*) and seasonal migration (0. 177) were principal household informal adaptation strategies to flood. This study recommends that formal adaptations measures be adopted by stakeholders as well as sensitization of the population on flood management options.

Keywords: anthropogenic,drivers, flood, coastal areas, adaptation

1. Introduction

The coastal areas in most urbanized societies represent an attractive migration destination, with an observed population increase of 15.3% from 2000 to 2017 and a total population of 94.7 million (Cohen, 2019). Further, 19 million residents live within 1 km of the coastline and 11.6 million below 3 m above sea level, placing them at a heightened risk of coastal flooding (Lam *et al.*, 2009). At the same time, many coastal urban areas with low elevation and flat topography are experiencing intensified and episodic flooding affecting their natural and human systems (Cohen, 2019) and the overall livability in the coastal communities (Frey, 2022; Nicholls and Cazenave, 2010; Sallenger*et al.*, 2012).

Floods are the most important global form of natural hazards in contemporary Africa and accounted for almost 83% of all disasters in Africa in 2010, causing an economic loss of $59.2 million in the same year (Guha-Sapir, Hoyois& Below 2013; Ozger 2017). The advanced inundation model using the improved Digital Elevation Model (DEM) shows that one billion people reside in areas less than 10 m above high tide while 230 million live below 1 m, making them physically vulnerable to sea level rise and chronic coastal flooding (Kulp and Strauss, 2019).

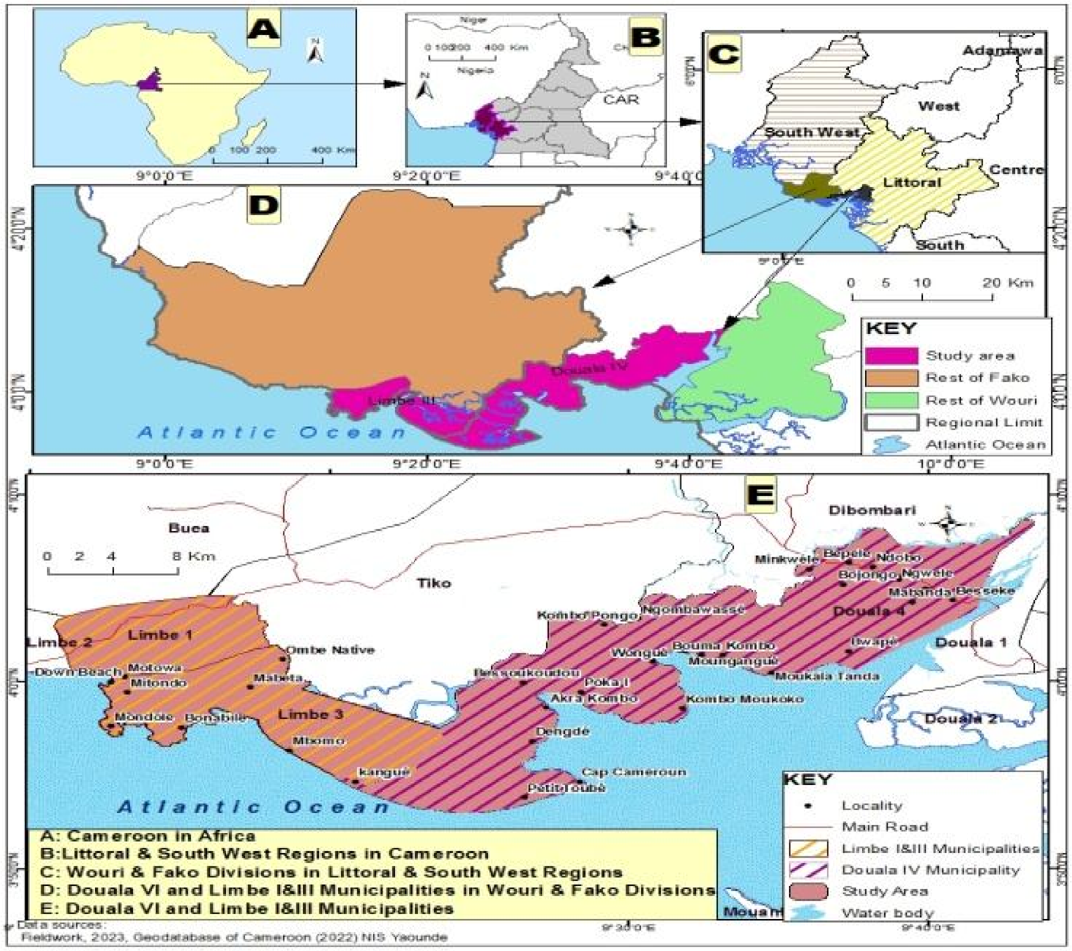
Attributing coastal flooding to only sea level rise caused by global climate change/variability can be somewhat inaccurate as certain mechanisms (engineering incline) also trigger flooding in coastal areas (IPCC, 2018; ActionAid, 2006; Douglas *et al.*, 2008; Joshua *et al.*, 2017; Rice & Steinko 2012; Satterthwaite 2008; Satterthwaite *et al.* 2007; Yolar*et al.,* 2019). Furthermore, institutions for hazard management in many developing countries are very weak (Balgah et al. 2016; Bang 2014)

The consequences of floods are now a terrifying reality in coastal environments; yet, managing their impacts remains one of the greatest contemporary challenges. Human's adaptations are aimed at taking advantage of the situation or reduce the adverse effect melted on them. While the concept of adaptation has gained increased attention, its realisation is still a work in progress (Smit &Pilfosova, 2001; Sperling, 2003; Lwasa, 2010; Quade & Lawrence, 2011; Munroe *et al.*, 2012; Odemerho, 2015).Often, households mayapply either adaptive or coping strategies. Whilst former aim at minimizing floods risks, the latter areemployed to deal with their aftermaths (Serre *et al.*, 2016).Often, victims prefer preventive strategies, but haveno option than to adapt in their absence (Berman *et al.*,2014). Some adaptive and coping measures employ formaland informal instruments. Informal instruments includeindividual, household or community-based actions whilstformal instruments are mainly publicinterventions.Informally, households adapt by raising flood barriers, building resilient structures and filling with soil to raise ground levels, placing valuables above the floor and (Isunju*et al.,* 2015; Andjelkovic 2001).The compound flood impacts in the coastal zone and limited households capacity to adapt makes these areas not suitable for habitation (Haasnoot*et al.,* 2021).Thus, there is need to implementeffective disaster management strategies by governments if they have to achieve theSustainable Development Goals (Clark, 2015)

3.Study Areas and Methods

3.1 Study Areas

Geographically, Douala IV Municipality (D4M) is located in Wouri Division, North of the Littoral Region. This Municipality covers a surface area of about 890Km^2 (Administrative Units of Cameroon, 2018). On the other hand Limbe I and III Municipalities (L1&3Ms) constitute two of the three Sub-divisions of Limbe. They are located between “3^o 95 - 4^o 00" North and longitude “9^o 12 -9^o 25" East of the Greenwich Meridian covering 212km^2. D4M and L1&3Ms make up part of the low-lying basin which runs from the foot of Mount Cameroon (4095m^2) to the southern part of Kribi (Gaston, 2009). These coastal areas enjoys equatorial climate with two seasons (hot and wet). The annual rainfall of D4M is more than 4000 mm with average daily temperatures of 25˚C while L1&3Ms have average annual rainfall between 3100mm - 5000mm with average daily temperature of 24˚C (NASA, 2022). Figure 1 shows the geographical location of the study areas.



Map 1: Location of Study Areas

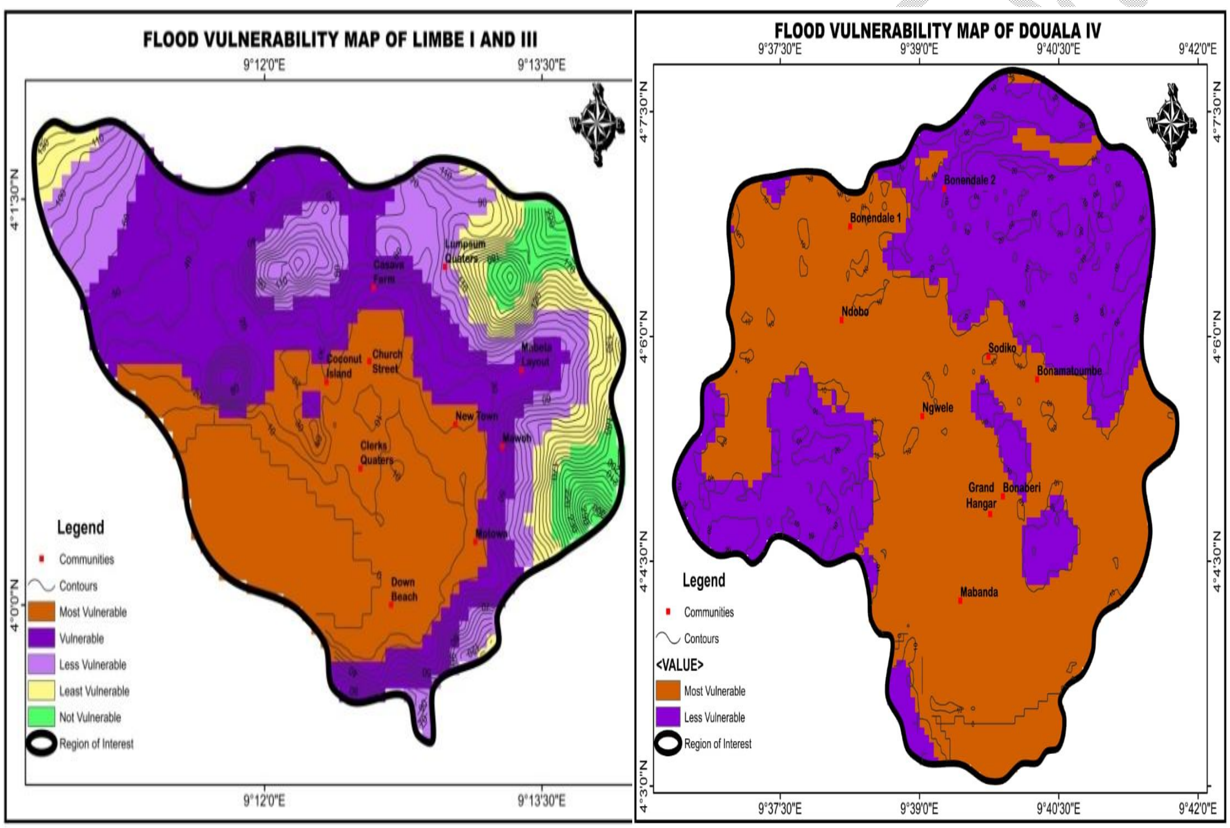
Source: Geo database of Cameroon, 2022, NIC

3.2 Study Methods and Data Analysis

A mixed research design was used in this study.The sample size of the study was selected from the number of households in the different neighbourhoods obtained based on the 2020 population data gotten from the Limbe City Council and Douala Urban Council.Stratified random sampling technique was adopted and 390 respondents constituted the sample size derived from the Fisher's formula.A total of 384 respondents constituted the sample population for administered household questionnaires in the study while 6 interviews were administered to stakeholders within the study areas.Data was entered into EpiData Version 3.1 and analyzed using IBM Statistical Package for Social Science (SPSS) version26. A predictive decision model was drawn from Digital Elevation Map (DEM) of the study areas to show levels of vulnerability to flood hazards in L1&3Ms and D4M. The model holds as a premise that all slopes below 2m are liable to flooding.

4. Results and Discussion

Like most Cameroonian coastal cities, the study areas are very exposed to flooding risks. This is linked to two groups of factors: anthropogenic factors (river beds occupancy, absence of canalizations and lack of maintenance of hydraulic equipment) and natural factors (rainfall, geology, sea proximity and topography).Five categories of neighbourhoods are found in L1&3Ms and two for D4M base on predictive map of flood vulnerability. These categories include; vulnerable, less vulnerable, least vulnerable and most vulnerable neighbourhoods. The most vulnerable communities include Down Beach, Clerks Quarter, Church Street, Motowo, Coconut Island and New Town for L1&3Ms and Mabanda, Grand Hanger, Ngwele, BonendaleI, Sodiko and Ndobo for D4M. The less vulnerable area is Lumpsum while the vulnerable areas are Cassava Farms, Mabeta New Layout and Mawoh (L1&3Ms) andBonasama, Bonamatoube, Bilingue, Rai and Bonendale II (D4M).Map 2 shows flood vulnerability in the study areas.



Map 2: Predictive Map of Flood Vulnerability for L1&3Ms and D4M

Source: Fieldwork, (2023)

Very high flood prone areas cover 55.10 Km² and 66.37km^2 of the urban areas of D4M and L1&3Ms.A prominent example of high flood-prone area in Douala IV is the Mabandaneighborhood (it covers an area of 5.19 Km²), located at the west of the city, on the right bank of the Wouri River. This quarter is the most flood-prone in D4M, for two reasons; the first is the altitude and the second is the sea proximity. Morphometric characteristics of the Mabanda drainage basin favours water accumulation. The altitude is very low, (average of 6m a.s.l); this is accentuated by slopes which are equally very low. This favours water retention rather than flow. Thus, in case of torrential rainfall, channel saturation is quick, causing flooding in Mabanda and nearby neighbourhoods.On the other hand, Clerk's Quarters and Down Beach in Limbe I Municipality have similar characteristics with Mabanda and covers 4.95km^2 at an altitude of less than 20m a.s.l. Some areas within these neignbourhoods are permanently flooded all year round owing to their low lying nature and morphometric characteristic. Similarly, Kulp andStrauss, 2019 using the advanced inundation model using theimproved Digital Elevation Model (DEM) showed that 230 million people live below1 ma.s.l, making them physically vulnerable to coastal flooding.Table 1 presents drivers for the increasing occurrences of flooding in the study areas.

Table 1: Drivers of Flooding in the Study Areas

Drivers of Flooding	Mean	
	L1&3Ms	D4M
1.Engineering drivers		
Poor drainage facilities e.g. low heights of bridges and narrow runoff channels	3.63	3.25
Haphazard settlement construction. e.g. encroachment on river channels	3.57	3.69
Inadequate design of drainage e.g. limited culverts, no drains	3.67	3.69
2. Non- engineering drivers		
Wetland reclamation	3.90	3.26
Blockage of drains by refuge or sediments	3.75	3.74
Nature of topography	2.97	2.26
Increase rainfall intensity and amounts	2.97	2.26

Source: Fieldwork, (2022)

From Table 1, flood triggers can be grouped into two; engineering and non- engineering drivers. The main engineering driver of flooding is inadequate and poorly designed drainage facilities. These include limited culverts and complete absence of drains in some localities within L1&3Ms which were strongly agreed upon with a mean score of 3.67 by the households. This was closely followed by poor drainage facilities e.g. low heights of bridges and narrow runoff channels with a mean value of 3.63 (strongly agreed) and haphazard construction of settlement (3.57-strongly agreed). Correlation analysis shows a significant relationship betweenpoor drainage facilities (p = 0.00582**), inadequate drainage facilities (p = 0. <0.0001***), haphazard settlement construction(p = 0.0597*), blockage of drains by refuge (p = 0.0888*) and severe coastal flooding and respectively. Findings corroborate the works of Haasnoot*et al.*,2021; Neal*et al.*, 2018 who opined that flooding outcomes may also transpire due to oversight of complexities in coastalsettings, lack of funding for policy implementation and enforcement.

The major drainage facilities and designs (bridges, gutters and culverts) in Limbe I and III Municipalities were sedimented and bridges had very low heights which could not accommodate high flooding volumes. This accounts for the increasing frequencies of flood waters after torrential downpours. On the other hand, D4M participants (with 3.96 mean score) noticed that haphazard constriction of settlements and inadequate designs of drainage facilities are the primary drivers of flooding. Similarly poor, drainage facilities were strongly agreed with a mean of 3.25 on the scale of 4 as being the second most engineering driver of meteorological risk for D4M. Similarly, Fombe and Molombe (2015) opined that the spread of uncontrolled settlements in different ecologically fragile terrain of Limbe has aggravated flooding especially with the anarchical Construction of Settlements along the Djenguele river channels within Limbe.

Based on the non-engineering drivers within L1&3Ms, wetland reclamation and blockage of drains by refuse had mean scores of 3.90 and 3.75 representing strongly agreed options from the households. D4M witnessed a great affirmation from households pertaining to the non-engineering drivers of floods as blockage of drains by refuse or sediments (3.74) and wetland reclamation (3.26) was strongly agreed upon. These drivers were equally explained by an interviewed council worker when he said:

> *Flooding in Limbe is triggered by factors such as inadequate drains, uncontrolled waste disposal, reclamation and drainage of wetlands, human encroachment on river channels, nature of rainfall and poor drainage conditions (interview with council worker, 2022)*

The mean depth value of right drains in selected neighbourhoods in L1&3Ms and D4M varies. The highest right drains recorded a mean depth score of 84.5cm (Sodiko) as opposed to 83.75cm for left drain (Ngwele). For L1&3M, Down Beach (63cm and 55.56cm) for left and right depths respectively. The highest depth were recorded in D4M (95.5 and 80.5cm) for the left and right drains. These drains however were either clogged by refuse, disjointed or in some areas were completely absent. Certain areas like Lumpsum, Mawoh Quarters, Motowoh Quarters and Mbonjo where there are no drains, recorded heavy flood damages. Drains which could have contained the runoffs are completely absent in these quarters. Consequently runoffs usually flood the adjacent settlements.These factors contributed to increasing the issues of flooding.Despite the existing water channels, drains are constructed without considering the maximum volume of water expected to flow through them during the rainy periods. Thus, during the rainiest months (August, September and October), settlements along Djenguele River and Limbe River suffer from flooding causing the destruction of properties, livelihoods and loss of human lives. While for D4M, the habitual clogging of drains by refuse and the complete absence of drains in some neighbourhoods has contributed to accelerating flooding.

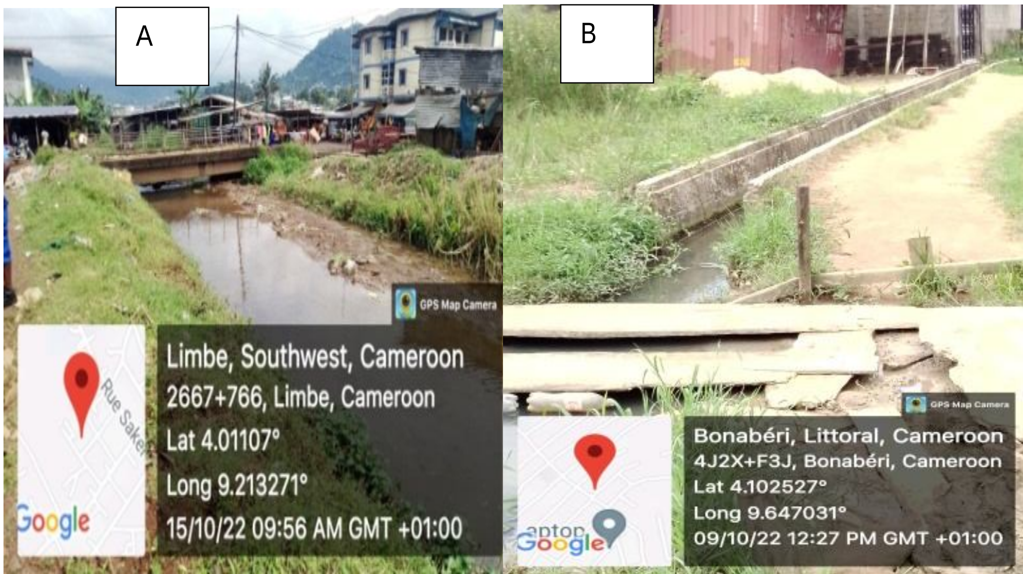


Plate 1: Engineering Drivers of Flooding in D4M and L1&3Ms

Low height of bridge (A), and inadequate design of drainage facilities (B)

Source: Fieldwork, 2022

Field surveys also revealed that human encroachment on river channels is also perceived by participants as triggers of flooding in the study area. Uncontrolled/haphazard settlements in a difficult and unstable terrain in L1&3Ms occur on low lying areas and steep slopes as opposed to the plain-like relief of D4M. The issues of uncontrolled/haphazard settlements are accentuated by poor housing standards and lack of basic engineering amenities like proper drainage channels (storm drains/culverts) in some neighbourhoods. The expansion of settlements even to river banks and urban agriculture has led to the clearance of the wetlands that hitherto served as a check to various forms of excess water. The population increase and the increase in the demand for housing, results in anarchical construction especially along the river channel, consuming part of the river channels, causing the river to meander, slowing down its speed and resulting in flooding. Plate 2 shows human encroachment on the river channel in L1&3Ms (A) and D4M (B)

Plate 2: Anarchical Construction of Settlements DjengueleRiver-Limbe

Source: Fieldwork, 2022

Field observations (Plate 3) show that some houses are constructed across river channels, partially blocking the normal flow of streams or runoff. Flooding is induced as the sediments eroded from the slopes raise the river beds and clog the narrow drainage channels or storm drains alongside solid wastes. This then leads to flooding, residential inundation and the problem of sedimentation and subsidence in the low lyingneighborhoods in areas like Mawoh, Church Street, New Town, Down Beach, Clerks Quarters and Mbonjo. Despite the important role now played by the Hygiene and Sanitation Company (HYSACAM) in solid waste management, the problem of solid wastes clogging the storm drains and river channels still persists in the study areas.The clogging of drains by debris especially nonbiodegradable wastes in quarters like Church Street, Clerks quarters, Motowoh, Down beach, Mabando, Ngwele, Ndobo and Bonendaleleads to siltation and suffocation of the drains/river channel, causing flooding. Adaptation/coping mechanisms are indispensable to offset harm emanating from floods in coastal areas. Therefore, it is necessary to identify existing adaptation practices in the study areas (Table 2).

Table 2: Households Adaptations against Flood

Options	Mean	
	L1&3Ms	**D4M**
a) Engineering		
Raising a barrier wall	3.70	3.14
Filling with soil to raise foundation	2.49	2.98
Digging trenches around the house	2.63	2.78
b) Non- engineering		
Raising the bed higher above the floor	2.90	3.30
Desilting regularly the drainage channels	2.59	1.00
Placing valuable items above the floor	3.11	2.98
Seasonal migration	2.42	1.69

Source: Fieldwork, (2023)

From Table 2, on the basis of a four pointlikert scale, based on the engineering options, households in L1&3Ms and D4M agreed to raising barrier walls around their homes with mean values of 3.70 and 3.14 respectively. Households in L1&3Ms also stated that they dig trenches around homes and raise the foundation of their houses (with mean values of 2.63 and 2.49). Based on the non-engineering adaptation, households in L1&3Ms strongly agreed that they placed valuable items like documents and certificates above the floor preferably in the ceiling and raising their beds higher above the floor with mean values of 3.11 and 2.90 in L1&3Ms respectively. On the other hand, in D4M, households accepted that they raise their beds higher above the floor, place valuable items above the floor and abstain from building across water ways (with mean scores of 3.30, 2.98 and 2.95 respectively). Construction on raised foundation (p = 0.0439**), raising bed higher above the floor (p = 0.0370**), placement of valuable items above the floor (p = 0.0613*) and seasonal migration were the most important informal adaptation strategies. Equally, there is a significant relationship between raising a barrier wall and flood adaptation with p-values of 0.003/0.004 for L1&3Ms and D4M respectively. Findings of this study are similar to those Isunju 2015; Isunju*et al.,* 2013, 2016 on households adaptation to flooding in the slumps of Kampala-Uganda.

While building resilient structures might be protective against flood risk, other factors such as location, severity of floods, and construction materials could affect the level of protection. This finding is in relation to the work of Sunju and Fuanyi (2020) who indicated increasing exposure of African coastal communities to floods. Although several households exposed to floods in the study areas also adapted by raising embankments along the drainage channels and digging drainage canals, these adaptations were often at neighbourhood scale.Plates 3 show some adaptations against flooding in the study areas.

Plates 3: Addressing the Negative Impacts of Flooding in the study areas

Source: Field work, 2022

Moreso, households also engaged in seasonal migration especially in L1&3Ms with a mean acceptance score of 2.42. Seasonal migration from flooded zones to semi flooded zones was exemplary in the study areas as some household's temporary relocate during peak flood periods of August and September and only return at the end of the wet season. Similarly, Anamaria & Barnett 2013, in the study of drivers of flood-induced relocation among coastal urban residents in US East Coast found out that 87% of respondents considered relocating due to coastal flooding. For those who chose not to relocate to other areas, because they do not have relatives out of their immediate residences or other reasons, adapting to flooding were reported to be quite stressful and significantly lowered the quality of life for those affected. A council worker in Limbe III Municipality gave these insightful worries-some experience when he lamented that;

> One time the rain came when we were sleeping and the whole house was flooded so at night when I hear the thunderstorm I get. We cannot relocate because of our large family size and also my mother is aged. Leaving with her to a relative's house is bothersome. Aside being a council worker, I am also a farmer but my income is so small that relocating to another area during peak periods will warrant that I rent another house if I don't want to bother my relative up in town. Tell me, where will I get the money to rent, transport our entire luggage and to return when floods are over? I rather suffer with my family here and manage the situation.

Thus, the preference of some households staying during flooding episodes is due to financial constraints, large family sizes and age barrier. Early research focused on hazard exposure as a primary reason for relocation. However, emerging evidencesuggests that many other place-based factors such as age and income barriers strongly influence the decision to move beside the hazard exposure (Tubridy *et al.*, 2022).

5 Conclusion and recommendations

This paper has assessed the drivers flooding and household informal adaptations. The findings haverevealed thatengineering factors, forinstance positively affectsexposure to whilst raising foundation and placing valuable items above the ground were crucial for coping decision-making. Given the current status quo, it seems plausible to hypothesisethat flood victims in the study area are more likely todepend heavily on informal coping strategies. However, given the opportunity, they wouldappropriate formal instruments to copewith flood hazards. In the meantime, perhaps, stakeholders should intensify on prevention and preparedness options for flooding in the coastal areas of Limbe and Douala IV.

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