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Anthropogenic Drivers of Floods and Household Adaptations Across the Coastal Wetland Areas of Limbe and Douala IV Municipalities, Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ALF and MOB went to the field, collected and analysed the data. Author ALF drafted the research design and protocol which were corrected by authors TES and BSN. Author ALF equally drafted the manuscript which was revised by author TES and BSN. All authors read and approved the final manuscript.

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ABSTRACT

Many coastal wetland areas are experiencing the impacts of accelerated and episodic floods on the built environment and people's livelihoods. This work examined the anthropogenic drivers of floods and household adaptations in Limbe and Douala IV Municipalities-Cameroon. Data was generated from primary and secondary sources and analysed using Statistical Package for Social Science version 26. Findings revealed that areas between 1-5m such as Clark's Quarter, Down Beach, Mabanda and Ndobo witnessed severe floods. There was a statistically significant relationship

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between poor drainage facilities, haphazard settlement construction, blockage of drains by refuge and severe coastal flooding with probabilities values of (0.00582**, 0.0001*** 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 (p=0. 177) were principal informal adaptation strategies to floods. This study recommends proper land use planning by stakeholders.

Keywords: Build-up expansion; coastal wetlands; floods; land use planning; Limbe; Douala IV.

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" [1]. "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" [2]. 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 [1] and the overall livability in the coastal communities [3-5].

"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" [6,7]. "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" [8]. 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 [9-15], Furthermore, institutions for hazard management in many developing countries are very weak [16-18].

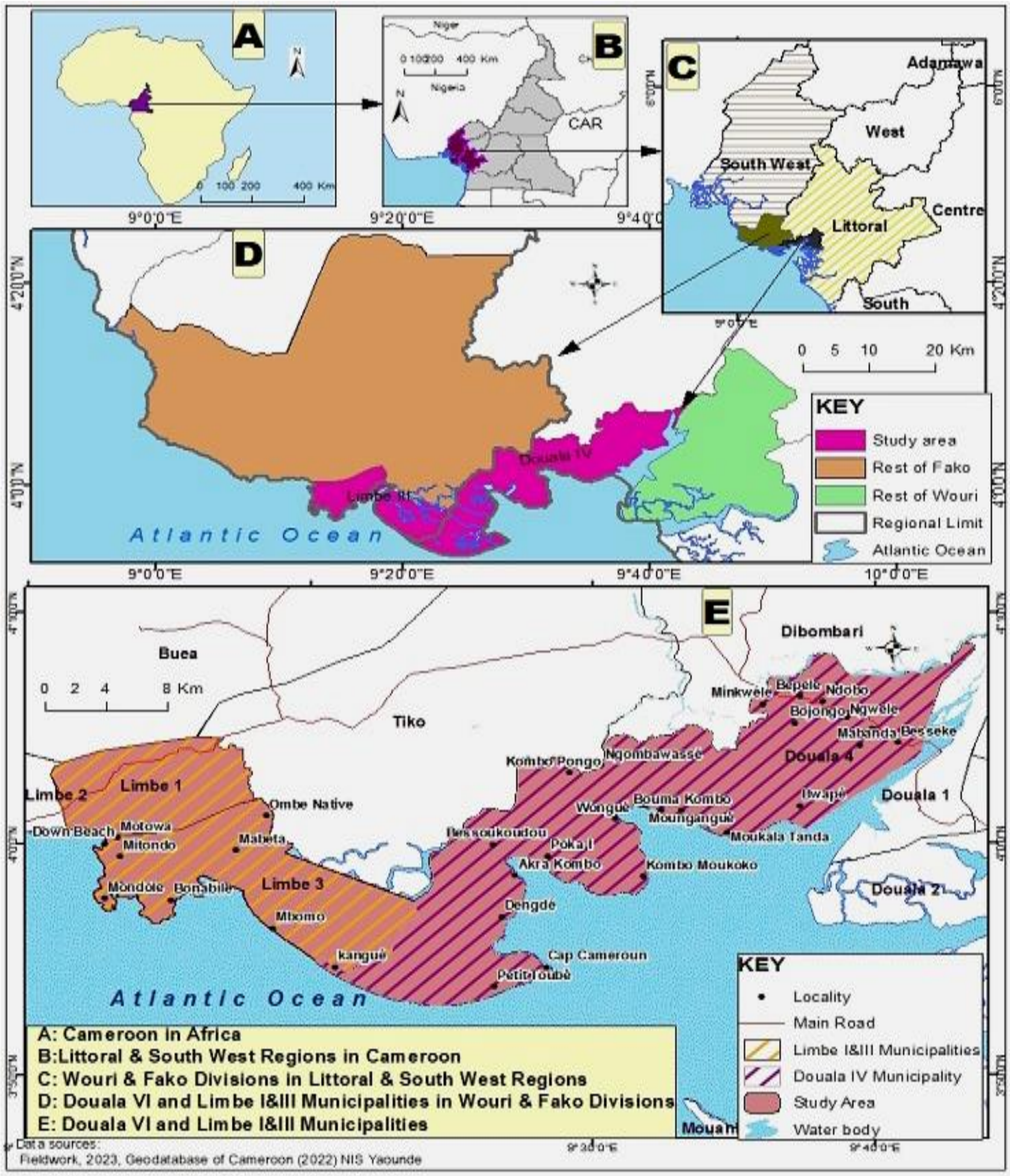
The consequences of floods are now a terrifying reality in coastal environments; yet, managing their impacts remains one of the greatest contemporary challenges. Human's adaptations are aimed at taking advantage of the situation or reduce the adverse effect melted on them. While the concept of adaptation has gained increased attention, its realisation is still a work in progress [19-24]. Often, households may apply either adaptive or coping strategies. Whilst the former aim at minimizing floods risks, the latter are employed to deal with their aftermaths [25]. Often, victims prefer preventive strategies, but have no option than to adapt in their absence [26]. Some adaptive and coping measures employ formal and informal instruments. Informal instruments include individual, household or community-based actions whilst formal instruments are mainly public interventions. Informally, households adapt by raising flood barriers, building resilient structures and filling with soil to raise ground levels, placing valuables above the floor and [27,28,15,29,30]. The compound flood impacts in the coastal zone and limited household's capacity to adapt makes these areas not suitable for habitation [31] yet the population of these areas keep growing [18]. Thus, there is need to implement effective disaster management strategies by governments if they have to achieve the Sustainable Development Goals [32]. Independent scholarly works exist on flood occurrence in the coastal milieu [33,34,15,35], informal adaptations [27,36, 30] but very little attention has been paid to understand the nexus between anthropogenically driven floods and households adaptations in coastal areas of the study reason for which this research sets in to bridge such gaps. This work sets out to answer the following questions;

1) Which are the major anthropogenic drivers of floods in the study areas?
2) What household's adaptation strategies have be employed?
3) How can stakeholders intervene to remedy the impact of anthropogenic triggered floods in the study areas?

2. STUDY AREAS AND METHODS

2.1 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 power data). Fig. 1 shows the geographical location of the study areas.



Map 1. Location of Study Areas
Source: Geo database of Cameroon, 2022

Table 1. Sample Population from Nieghbourhoods

Questionnaire Administration						**Interviews**
Nieghbourhoods	**Quadrants**	**Target Population**	**% of Total Population**	**Sampled households**	**% of Sample Population**	
Lumpsum	Limbe	1098	0.38	11	2.86	2
Down Beach		1720	0.59	15	3.90	
Clerks Quarters		3890	1.34	23	5.99	
New Town		1083	0.37	13	3.39	
Church Street		2997	1.03	19	4.95	
Mawoh		8976	3.09	31	8.07	
Bonaberi	Douala IV	91,350	31.42	62	16.93	2
Bonendale 2		8,102	2.79	24	6.25	
Rai		29,123	10.02	46	11.98	
Ndobo		11,200	3.85	29	7.55	
Mabanda		91,796	31.58	63	17.44	
Ngwele		39369	13.54	41	10.69	
Total	2	290704	100	380	100	4

Source: Extracted from population Statistic (2005) and Updated from Bonasama and Limbe City Councils Database (2024)

2.2 Study Methods and Data Analysis

This study adopted a case study research design, using questionnaire, field observations and interviews in gathering data. A total of 384 rrespondents who had lived in the study areas for 5 years and above were chosen as they had mastery of the issues under investigation. The questionnaires were semi-structured to ensure greater precision and uniformity and also to allow participants capture aspects which were not structured in the questionnaire. Where necessary, respondents were asked to rank their degree of agreement or disagreement with respect to the different questions found on the questionnaire on a four (4) points Likert scales. The scale ranges were 3.00 to 4.00 for strongly agree, 2.00 to 2.99 for agree, 1.00 to 1.99 for disagree and 0.99 to 1.00 for strongly disagree. Data was entered into EpiData Version 3.1 and analysed using IBM Statistical Package for Social Science (SPSS) version 26. 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 floods. The sample population was drawn from the study population (Table 1).

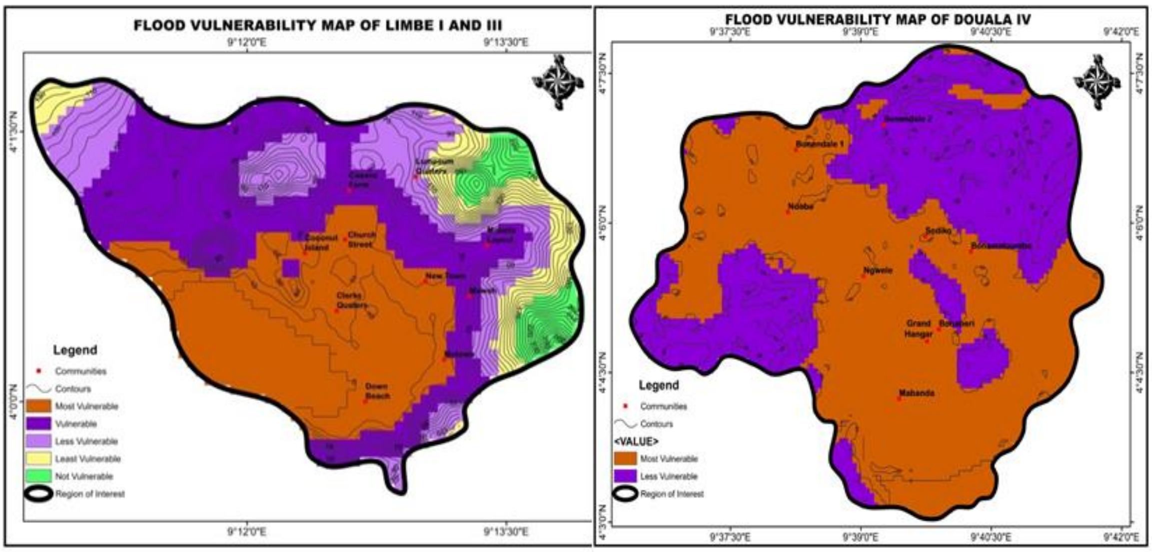
Wetlands degradation for housing has been documented as one of the principal driver of floods. Moderate resolution Landsat images from the United States Geological Surveys (USGS) and Google Earth Explorer websites (http://glovis.usgs.gov/) were downloaded to analyse build-up expansion and wetland changes for the past 36 years. The Images were imported into Erdas Imagine, 2014 where preprocessing was done and Supervised Classification based on maximum likelihood was adopted for the processing of the image to generate a raster format depicting the designed wetlands and built-up which constituted the major themes.The end results from Arc GIS 10.3 software analysis provided the spatio-temporal trends of build-up expansion and wetland land cover changes in the study areas (1986, 1999, 2013 and 2022). The analysed data were presented in the form of tables, figures and maps. Ethical consideration was strictly implemented, and inhabitants' concerns were sought before administering the questionnaires.

3. RESULTS AND DISCUSSION

Like most Cameroonian coastal cities, the study areas are very exposed to flood 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, Bonendale I, 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) and Bonasama, Bonamatoube, Bilingue, Rai and Bonendale II (D4M). Map 2 shows flood vulnerability in the study areas.

Very high flood prone areas cover 55.10 Km^2 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 Mabanda neighborhood (it covers an area of 5.19 Km^2), 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 as the 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 neighbourhoods are permanently flooded all year round owing to their low-lying nature and morphometric characteristic. Similarly, Kulp & Strauss, 2019 using the advanced inundation model using the improved Digital Elevation Model (DEM) showed that 230 million people live below 1 m a.s.l, making them physically vulnerable to coastal flooding. Housing development and decrease in wetland areas were documented as some of the major drivers of floods in the study areas (Maps 3 and 4). Findings revealed that the built-up areas expand to peripheral areas at the detriment of wetlands.

The total area covered by built-up grew from 10.89km^2 in 1986 to 43.34 km^2 in 2022 indicating a magnitude of increase of 32.45 km^2 within the same period in D4M. However, a lesser magnitude of increase of 6.96 km^2 was recorded between 14 years period (1986-1999) indicating an increase from 10.89 km^2 to 17.85 km^2. Equally, between 1999-2013 (13 years) built-up in D4M recorded a magnitude of increase of 8.26 km^2, indicating an increase from 17.85 km^2 to 26.11 km^2. Analysis showed that between 2013-2022 (8years) the magnitude of increase of built-up skyrocket by 17.23 km^2. By implication, built-up in D4M increased significantly over a shorter period (2013-2022) as opposed to the other periods. This was attributed to population growth and the need for shelter. Increase in built-up led to a significant decrease in wetland area thus reducing its regulating ecosystem function. In the year 1986, wetlands occupied 32.81km^2 of 252.2 km^2 land surface of the Municipality. However, this area covered decreased from 32.81 km^2 to 31.80 km^2 in 1999 indicating a decreased of 1.01 km^2. Also, in the year 2022 wetlands occupied 17.17 km^2 of the total land area of D4M indicating a drop of 8.84 km^2 (26.01 km^2 to 17.17 km^2). Map 4 and Fig. 2 shows built-up expansion in L1&3Ms.



Map 2. Predictive map of flood vulnerability for L1&3Ms and D4M
Source: Aminkeng, Tata & Balgah (2024)

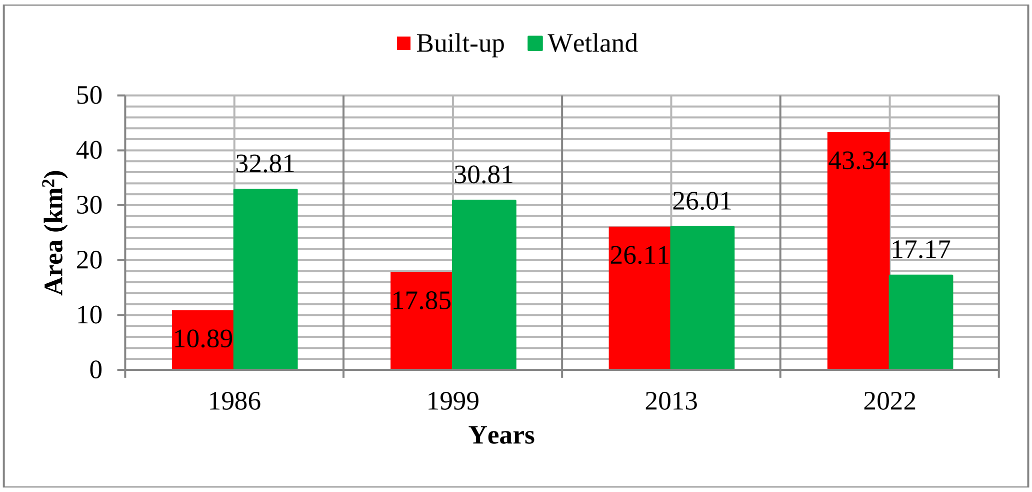
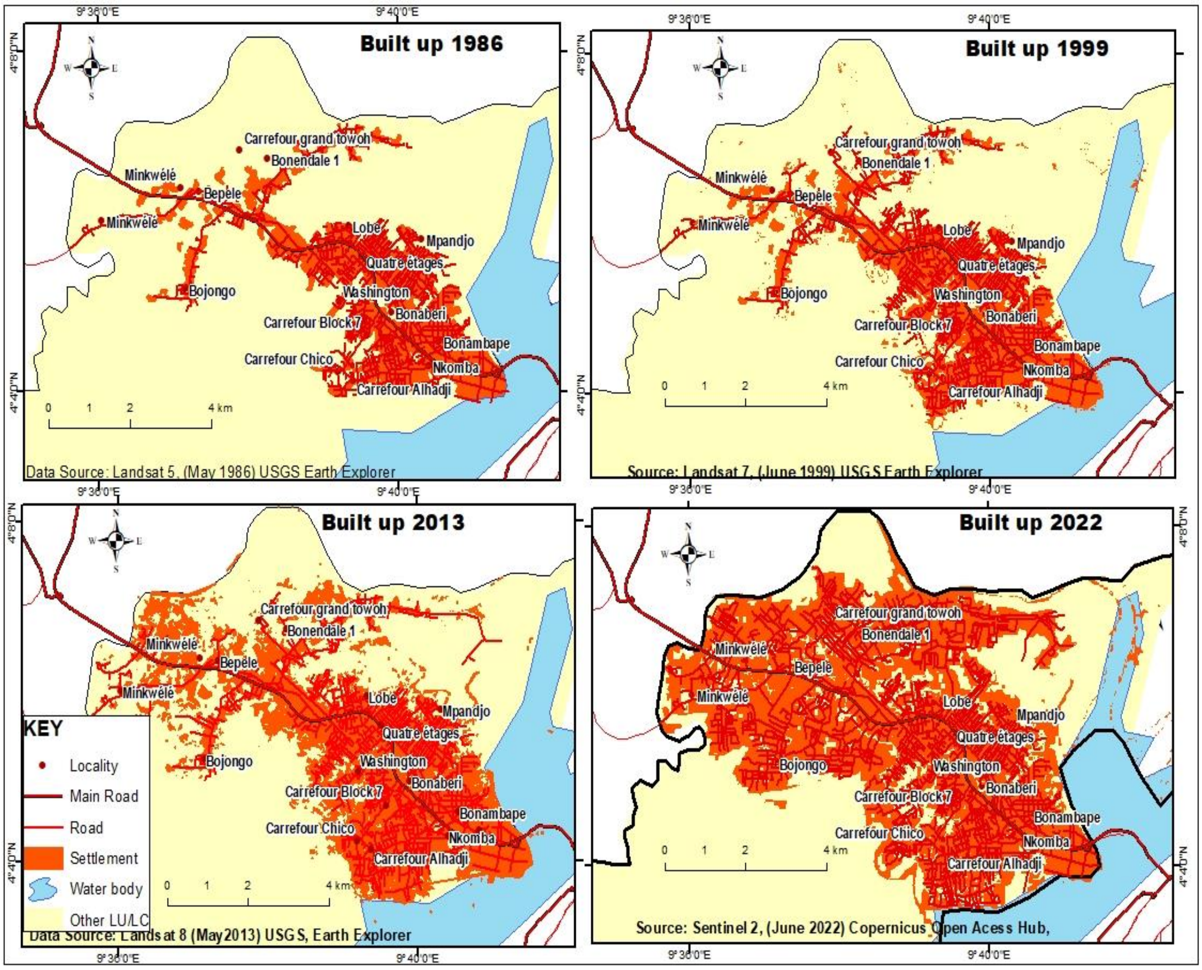


Fig. 1. Built-up Expansion in Douala IV Municipality Coastal Wetlands as Driver of Floods (1986-2022)

Source: Landsat 5 1986, Lansat 7 1999, Landsat 8 2013 and Sentinel 2, 2022



Map 3. Built-up situations in the coastal wetlands of Douala IV Municipality for 1986, 1999, 2013 and 2022

Source: Landsat 5 1986, Lansat 7 1999, Landsat 8 2013 and Sentinel 2, 2022

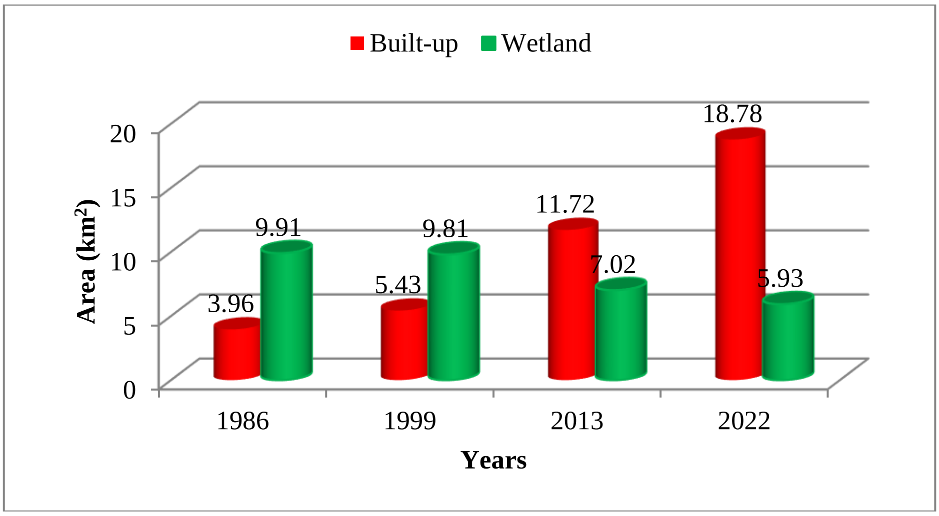
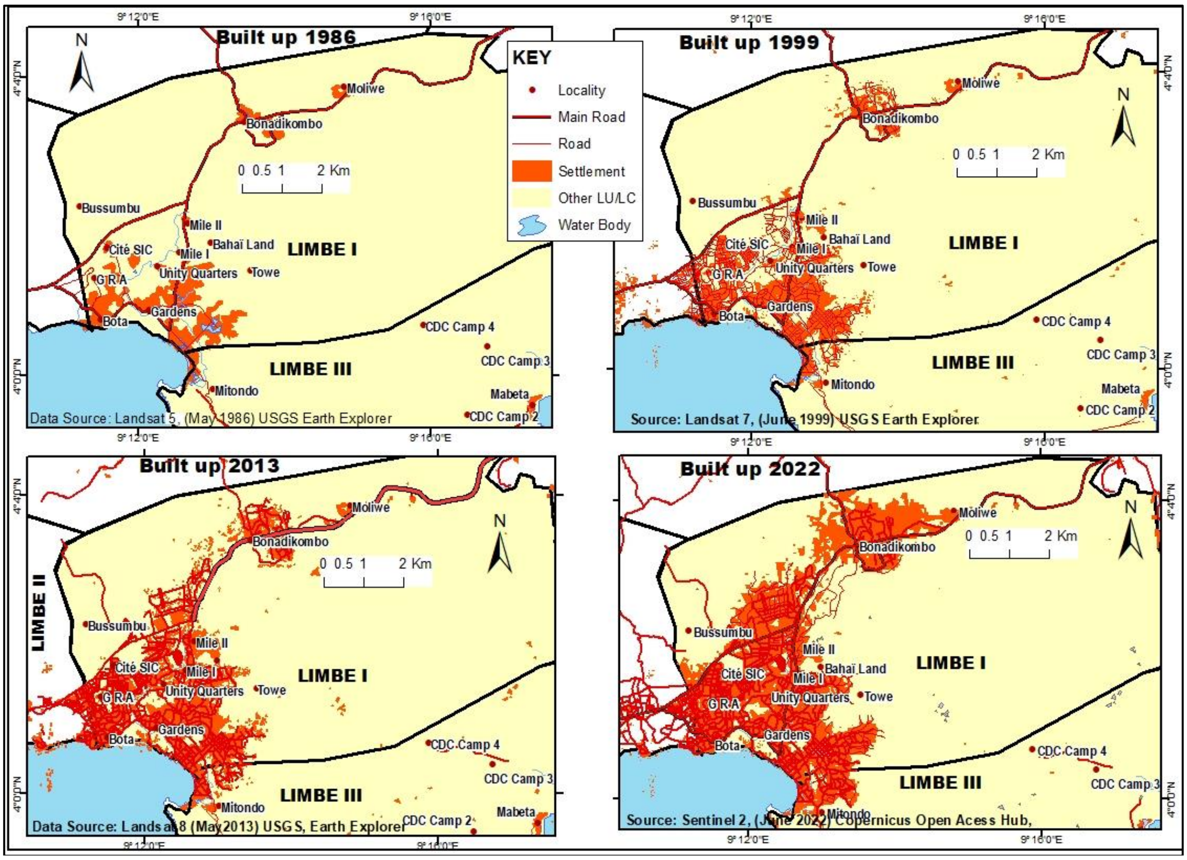


Fig. 2. Built-up Expansion in the Coastal Wetlands of Limbe I and III Municipalities as Driver of Floods (1986-2022)

Source: Landsat 5 1986, Lansat 7 1999, Landsat 8 2013 and Sentinel 2, 2022



Map 4. Built-up Situations in the Coastal Wetlands of Limbe I and III Municipalities for 1986, 1999, 2013 and 2022

Source: Landsat 5 1986, Lansat 7 1999, Landsat 8 2013 and Sentinel 2, 2022

From Map 4 and Fig. 2, the total area covered by built-up in L1&3Ms grew from 3.96km^2 in 1986 to 18.78 km^2 in 2022 indicating a magnitude of increase of 14.8 km^2 within the same periods. However, a lesser magnitude of increase of 1.47km^2 was recorded between 14 years periods

(1986-1999) indicating an increase from 3.96 km^2 -5.43 km^2 (3.96 km^2 of increase). Equally, between 1999-2013 (13 years) built-up in L1&3Ms recorded a magnitude of increase of 6.29 km^2, indicating an increase from 5.43 km^2 - 11.72 km^2. In the year 1986, wetlands occupied 9.91km^2 of 207.79 km^2 land surface of the Municipality. However, this area covered decreased from 7.02 km^2 to 5.93 km^2 from 2013 to 2022 indicating a decreased of 1.09 km^2 arising mainly from increased built-up.

The built-up area in the study areas has developed significantly to the southwest and southeast of D4M, where the area is heavily concentrated with industrial expansion and in Limbe in the Southern areas concentrated by residential growth. Built-up lands in coastal floodplains are both drivers and consequence of complex socio-hydrological processes in the study areas. In the study areas, it drives flood hazard dynamics through altering hydrological and hydraulic processes as a result of both its extent and spatial pattern. This leads to the increasing subsidence on the land which resulted in increasing tidal inundations in Limbe. Thus, findings of built-up increase as driver of floods corroborate the study of Han et al*.,* [37] *who* examined the changes in the amounts, patch sizes, and types of Built-up land in floodplains (BLF) expansion and revealed their relationships with flood occurrence in China. This study posited that the Yangtze River Economic Belt (YREB) experienced rapid and massive BLF growth, from 8.75×10^3 km^2 in 1990 to 17.28×10^3 km^2 in 2014, or by 97.58%. Small-patch BLF and the leapfrogging BLF had much stronger correlations with flood frequency than that of the large-patch BLF growth and the edge-expanding BLF, while the infilling BLF was not significantly correlated with flood occurrence. Similarly, Khoirunisa, & Yuwono, [18] found out that the built-up area in Semarang City in 2010 occupied 36.27% of the city, and it increased to 59.79% in 2021, in eastern, south-eastern, and northern parts of in the last six years. Most of the built-up areas, especially those located in coastal areas, are located in areas with a high rate of land subsidence and urban flooding not just due to settlement expansion but also natural drivers like climate variability. Table 2 presents households perceptions of drivers of floods in the study areas.

From Table 2, anthropogenic flood triggers were 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 showed a significant relationship between poor drainage facilities ($p = 0.00582^{**}$), inadequate drainage facilities (p = 0. <0.0001***), haphazard settlement construction/wetland depletion ($p = 0.0001^{***}$), blockage of drains by refuge ($p = 0.0888^{*}$) and severe coastal floods respectively. 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 flood 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 flood risk for D4M. Findings corroborate the works of Fon and Mbella, [38]; Fombe & Balgah, [39]; Isunju [40], Nguh and Anumveh, [41], Sunjo & Fuanyi, [30]; Aminkeng et al*.* [15]; who indicated the increasing frequencies of occurrence of floods in coastal wetland areas to be exacerbated by river bed occupancy, poor households behaviours in terms of waste disposals, haphazard settlement construction in wetland environment, poor land use planning, inadequate drainage facilities and wetland reclamation for housing. On the other hand, Haasnoot et al*.,* [31]; Neal et al*.,* [42] opined that flooding outcomes may also transpire due to oversight of complexities in coastal settings, lack of funding for policy implementation and enforcement.

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 was 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 were 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.

Table 2. Households perceptions on drivers of floods in the study areas

Drivers of Floods	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 and degradation of wetlands	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)

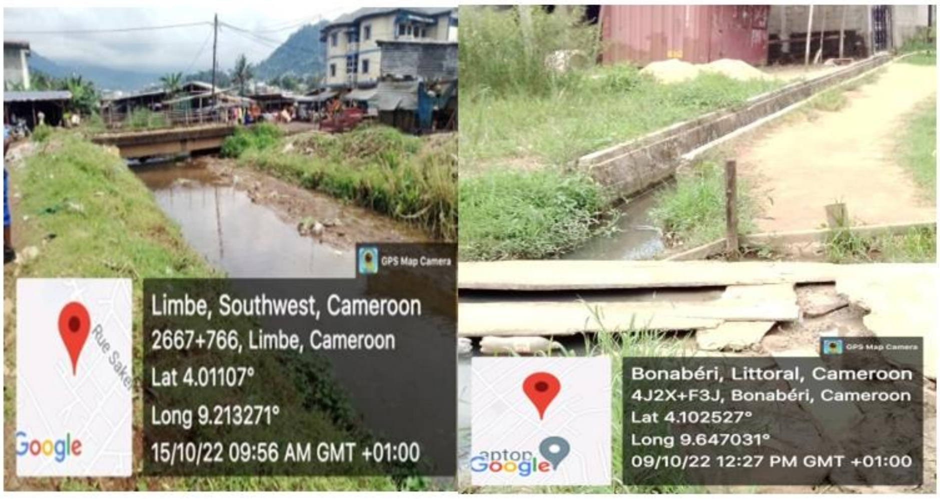


Plate 1. Engineering Drivers of Flooding in D4M and L1&3Ms
Low height of bridge (A), and inadequate design of drainage facilities (B)
Source: Fieldwork, 2022

Field surveys also revealed that human encroachment on river channels is also perceived by participants as triggers of floods in the study areas. 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). These findings corroborate the works of Douglas [43], Ajiboye, & Orebiyi, [44], Fogwe [33] who indicated that there exists an intricate relationship between engineering facilities and flooding within wetland environment as driven by urban expansion. These findings in part corroborate the scholarly works of Fon & Mbella [38] and Nguh and Anuveh [41] who opined that one of the principal drivers of increasing flooding in Limbe Municipality has been the narrowness of entrance of culverts.

Field observations (Plate 2) showed that some houses were 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 floods, residential inundation and the problem of sedimentation and subsidence in the low lying neighborhoods 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 especially in quarters like Church Street, Clerks quarters, Motowoh, Down beach, Mabando, Ngwele, Ndobo and Bonendale due to siltation and suffocation of the drains/river channels. As was opined by Yengoh *et al.,* [45], floods in Douala are not associated chiefly with changing rainfall patterns but rather, massive increase in population, poor planning, and little investments in city infrastructures and policy implementations whereby the population continues to colonize flood-prone areas. Adaptation mechanisms are therefore indispensable to offset harm emanating from floods in coastal areas (Table 3).

From Table 3, 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 was 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. 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 Sunjo and Fuanyi [34] who indicated increasing exposure of African coastal communities to floods. Findings of this study are similar to those Isunju [27], Isunju et al*.* [46,27] on households' adaptation to flooding in the slumps of Kampala-Uganda who indicated that households raise barrier walls, build resilient structures, as well as placed valuables above the flood and dug trenches around homes. Also, DPSIR framework indicates that in the events of risks such as flooding, affected persons or households tended to develop adaption mechanisms so as to minimize the impact or benefit from it. Contrary to the above findings, Andjelkovic [47], indicated that non-structural measures such as regulating land use and public education is necessary to mitigating flooding in coastal environments. By implications, just adopting good household measures such as placing valuables above the floor are not sufficient and cannot be effective if structural measures such as avoiding construction on risky environments or ensuring that sound engineering structures are a plausible way out to mitigating flooding in the study Municipalities.

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. Households also engaged in seasonal migration especially in L1&3Ms with a mean acceptance score of 2.42 [48,49]. 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. Plates 3 show some adaptations against flooding in the study areas.

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.

Plate 2. Anarchical Construction of Settlements along the Djenguele River- Limbe
Source: Fieldwork, 2022

Table 3. Households adaptations against floods

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)

Plate 3. Addressing the negative impacts of flooding in the study areas
Source: Field work, 2022

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 evidence suggests that many other place-based factors such as age and income barriers strongly influence the decision to move beside the hazard exposure [50-53].

4. CONCLUSION AND RECOMMENDA-TIONS

This paper has assessed the drivers flooding and household informal adaptations. The findings have revealed that engineering factors, for instance positively affects exposure to floods 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 hypothesise that flood victims in the study areas are more likely to depend heavily on informal coping strategies. However, given the opportunity, they would appropriate formal instruments to cope with flood hazards. Flood management policies in the study areas have not yet paid attention to the different influences of built-up expansion on flood risk. First, the vulnerability of households should be reduced via high-level structural measures, e.g., dikes and embankments. However, decentralized and formal adaptation measures can play a role in reducing flood risk such as proper land use planning, wet and dry flood-proofing buildings. They are typically cheaper and easier to be applied compared with structural measures. Additionally, cost-benefit analysis should be used as a solid foundation to ensure the cost-effectiveness of proposed flood adaptation measures as well as proper urban planning [15]. In the meantime, perhaps, stakeholders should intensify on prevention and preparedness options for flooding in the coastal areas of Limbe and Douala IV Municipalities.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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