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Vulnerability to coastal flooding and response strategies: The case of settlements in Cameroon mangrove forests

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ABSTRACT

Worldwide, millions of people experience coastal flooding each year, with devastating effects especially in rural coastal settlements in tropical developing countries. This paper investigates the vulnerability of local settlements in the Cameroon mangrove forest zone to flooding, and improves understanding of perceptions and responses to past and current coastal flooding. Six communities in the coastal mangrove forest zone of the extreme SouthWest of Cameroon were investigated. A questionnaire was administered to a total of 200 individuals supplemented by other participatory rapid appraisal tools. The ground positions of the sampled sites as well as their altitudes were recorded for subsequent geospatial analysis.Statistical analysis was performed to show trends. The coordinates of the study sites were superimposed on base topographic maps of 1965, to investigate coastal changes over a period of 43 years. Results show that: (1) changes in coastal area have occurred in the past 43 years either through inland retreat or seaward shifts and accordingly, settlements are differentially vulnerable; (2) settlement submergence, house damage, and landscape deformation are the key impacts of flooding; (3) coastal flooding promotes the deforestation of mangrove forest for fuel wood; (4) current adaptive measures include retreat of settlement, abandonment, and house design modifications; and (5) most adaptive strategies are reactive

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individual actions which are likely inefficient and unsustainable from a longer term perspective given their limited scope of implementation. The paper recommends external support to improve adaptive capacity in mangrove settlements, review and improvement of existing policies, and development of integrated coastal management strategy for the region.

1. Introduction

Climate-driven disasters have emerged as the most glaring challenge of climate change in recent decades, with floods being the most disastrous, frequent and widespread consequence (Dhar and Nandargi, 2003). Developing countries bear the primary burden of climate-related extreme events and regionally, South, South-East and East Asia, Africa and small islands are the most vulnerable (IPCC, 2007). Ninety-four percent of climate-driven natural hazards between 1990 and 1998 have occurred in developing countries (IUCN, 2007). In recent decades extreme floods have affected many areas around the world especially in developing countries, with resulting extreme economic damage and human misery particularly in rural areas (Mirza, 2003). With projected sea level rise due to climate change, flood occurrence is expected to quadruple by 2080 (Small and Nicholls, 2004). Although there are some uncertainties about the nature and magnitude of sea-level rise and climate change, scientific evidence implies that present day coastal issues will likely be exacerbated (Perez et al., 1999; FAO, 2009). This is particularly a concern given that coastal areas are among the most populated in most countries with an estimated 23% of the world's population living within 100 km distance of the coast, and <100 m above sea level (Molua and Lambi, 2007; Small and Nicholls, 2004). Sea level rise and extreme events will also likely result in degradation of protective coastal systems such as mangroves, further increasing the vulnerability of coastal settlements to flooding.

Significant destruction and human deaths due to flooding have been reported in many coastal African cities, including in Cameroon, within the last decade (Douglas et al., 2008; Feka and Ajonina, 2011; MINATD, 2007). The impacts on Africa's coastal megacities are exacerbated by concentration of development close to the sea, and are further expected to intensify with sea level rise (Adger et al., 2005;Ajonina et al., 2008; Vordzorgbe, 2007). In fact, flooding has been identified as a major factor preventing Africa's growing population from escaping poverty, and impeding the attainment of the United Nations 2020 goal of achieving significant improvement in the lives of the population (Adelekan, 2009; Action Aid, 2006). This is due to the fact that predominant enabling factors such as the lack of infrastructure to withstand extreme weather conditions, poor planning and governance challenges place the African coastal populations most at risk (Adelekan, 2009). Past attempts to quantify the impacts of floods on Africa's coastal cities (Douglas et al., 2008; MINATD, 2008) have typically focused on property damage/loss and human deaths (Baxter, 2005). Often these estimates are made on the basis of isolated events and impacts on ecological systems (Din et al., 1997; Ajonina and Usongo, 2001; Ajonina et al., 2005) while post-event stress on social systems has received lesser attention. At the same time, flood risk areas within less established settlements have not received the same level of attention as the mega cities.

Research also suggests that the magnitude of the adaptation challenge is not well understood, constrained by uncertainties about how adaptation is taking place (Berrang-Ford et al., 2011). This is true of Cameroon where little has been done to identify coping strategies to coastal flooding in the country. Ultimately, it is difficult to establish the adaptive capacity of the people and hence to mainstream local and indigenous strategies and resources into broad-based management and climate change adaptation mechanisms. In addition, many climate change studies in Cameroon establish the extent of climate change and its impacts, with only a few opting for the 'vulnerability-led' over the 'impacts-led' approach (Ayonghe, 2008; Molua, 2002; Sonwa et al., 2010, 2012a,b). Efforts to establish the extent of vulnerability of specific human and ecological systems on the ground and to investigate interactions between climate-influenced factors and human and ecological systems are regrettably limited.

The study attempts to fill this gap by examining the impacts of recurring coastal floods on the densely populated, rural coastal and small island settlements in the mangrove forest of Cameroon. The project seeks to investigate potential vulnerability of these low-lying areas (sometimes below 1 m above sea level) under a changing climate. Local and indigenous coping strategies to seasonal floods were examined and formed the baseline for further evaluation. The possibility of incorporating local and indigenous knowledge into Cameroon's National Adaptation Program of Action was also explored. Based on this objective, responses were sought to the following questions: what are the impacts of coastal flooding on mangrove settlements? Are people differentially vulnerable to coastal flooding? How do local dwellers cope with or adapt to the impacts of coastal flooding?

2. Impacts of Sea level rise and seasonal floods on coastal areas

According to the IPCC (2001), the warming of the earth will result in the melting of Alpine ice and thermal expansion of seawater, which will ultimately result in sea level rise. Climate change is also expected to result in the increased frequency and intensity of extreme events subjecting coastal areas to aggravated storm surges and floods (IPCC, 2007). The IPCC (1998) notes that a worldwide rise in sea level would inundate wetlands and low lands; erode shorelines; exacerbate coastal flooding; increase the salinity of estuaries and aquifers (and otherwise impair water quality); alter tidal ranges in rivers and bays; change the locations where rivers deposit sediments; change the heights, frequencies and other characteristics of waves; and decrease the amount of light reaching the sea floor. Over the past decades, there is increasing evidence of the acceleration of sea level rise (up to 2–3 mm/yr) (IPCC, 2001, 2007), which suggests an increase in the vulnerability of low-lying coasts already subjected to increasing storm surges and floods. In Africa, floods together with droughts and epidemics have emerged as the most frequently occurring natural disasters, accounting for 79% of all occurrences of natural disasters (Vordzorgbe, 2007).

The impacts of floods are numerous and varied and include degradation of natural coastal systems such as wetlands, beaches and barrier islands (which removes natural defenses to coastal areas), destruction of human settlements and infrastructure and the threatening of water resources by saltwater intrusions. Rapid population growth, urban sprawl, growing demand for waterfront properties, and coastal resort development have additional deleterious effects on protective coastal ecosystems. Within coastal mangrove forests seasonal floods can have adverse impacts on human livelihoods, affect ecological balance and cause environmental degradation (Nguyen, 2000). Possible outcomes include migration of mangrove forest inland or seaward, extinction of migratory bird species, endangerment of other plant and animal species, disruption of human settlements and ecosystems, coastal pollution, and the intrusion of salt water into groundwater and estuaries. Floods bring extreme hardship to mostly rural and subsistence livelihood based communities, who are among the most vulnerable to impacts from climate variability and change (Desanker and Justice, 2001).

3. Amplification of coastal flooding in Cameroon

In Cameroon, coastal and oceanic activities such as marine transportation of goods, offshore energy drilling, resource extraction, fishery, recreation, and tourism are integral to the nation's economy. An estimated 30% of Cameroon's population inhabits the coastal region including towns like Douala, Limbe, Tiko, and Kribi (Feka, 2005). The densely populated coastal mangrove forest zone of Cameroon has more than 75% of its population living in strips located at most 1000 m from the shoreline (in low lying settlements, sometimes below 1 m above sea level), making it the most exposed area to coastal flooding hazards in the country. Feka (2005) indicates that mangrove area conversion as a result of human habitation has not been evaluated in Cameroon, even though studies show that over 20–30% of West and Central African mangroves have been lost since 1980 due to exploitation by humans (see e.g., UNEP, 2007). This is a situation that ought to have been given more attention, since several studies have claimed that mangrove destruction further exacerbates the effects of coastal flooding. The growing population and significant economic activity along Cameroon's coast therefore contributes to its high vulnerability to coastal flooding (Ajonina et al., 2004; Asangwe, 2002, 2006; Din et al., 1997, 2001; Din and Ngollo, 2002).

Cameroon's coast is dominated by a depositional sedimentary environment with particular geomorphic character of sandy, and/or low lying swamps constantly influenced by saline water incursions from the Atlantic Ocean. The extremely faint slopes of the geomorphic features and the lagoon-creek complex are easily inundated from sea incursions (Asangwe, 2006). Coastal flooding from saline water incursion results in ecological stress through wetland loss, inundation and erosion, while the lagoon-creek complex is affected by hydro-geomorphic changes with adverse environmental consequences on the coastal settlements (e.g. settlement submergence, house damage, landscape deformation). This is a cause for concern given that climate change is likely to intensify coastal flooding and worsen many problems that coastal areas already face: shoreline erosion, coastal flooding, and water pollution affect man-made infrastructure and coastal ecosystems (IPCC, 2001).

Prior studies on vulnerability to flooding in Cameroon have focused on urban flooding impacts, mostly attributed to poor drainage and poor building codes (Fogwe and Lambi, 2001; MINATD, 2008). Other studies by Youmbi et al. (1999) and Folack and Gabche (2001) have predicted that coastal flooding due to sea level rise will eventually devastate the Cameroon coast, resulting in property damage/loss, and loss of human lives, causing significant trauma and inconvenience to the population. Societal vulnerability may also increase pressures on natural resources as well as exacerbate ongoing social and economic challenges of coastal dwelling communities (Adger et al., 2003, Nkem et al., 2010). The possibility of haphazard inter and intra settlement migration is likely under such conditions, potentially resulting in conflicts, which typically accompany such movements (FAO, 2009).

Flooding can also change the amount of sediment delivered to coastal areas, worsen erosion, and remove or damage wetlands in Cameroon (Asangwe, 2006). Rising sea levels could increase the salinity of groundwater and push salt water further upstream (Youmbi et al., 1999; Golladay and Battle, 2002; Frost, 2003). In Cameroon, coastal flooding is already increasing the salinity of most estuaries (Asangwe, 2002, 2006; Feka, 2005; Feka and Ajonina, 2011), thereby reducing their potability and threatening aquatic plants and animals that are sensitive to the increased salinity (IPCC, 2007).

Given current flooding impacts and the potential vulnerability to climate change, building adaptive capacity in coastal Cameroon is an urgent necessity. According to Tompkins and Adger (2004) and Sanford (2009), two broad reasons explain the potential vulnerability of low-lying rural areas within developing countries to coastal flooding: (a) their social, economic, political, and institutional characteristics do not create a favorable climate for the acquisition of an adaptive capacity commensurate with their level of exposure and sensitivity and (b) degradation of protective coastal systems such as mangroves, which serve as the first line of defense of coastal communities against extreme water levels increases exposure to storm surges. Insufficient or inappropriate shoreline protection measures, inappropriate knowledge of coastal conditions and appropriate management measures, fragmented and ineffective institutional arrangements, and weak governance are factors that impede the building of resilience to coastal flooding (Din and Ngollo, 2002; Doldman et al., 2006; Finkl, 2002; Moser, 2000; Kay and Adler, 2005). People exposed to coastal flooding are also differentially vulnerable, depending on their individual adaptive capacities (Adger et al., 2003). Localized investigations are therefore key to understanding the scope, nature, and extent of vulnerability, assessing the coping capacity of human communities, identifying adaptation options and building adaptation strategies (Acosta-Michlik et al., 2008; Gregory et al.,2006; IPCC, 2007).

4. Study area

The coastal mangrove forest zone of Cameroon occurs in the extreme south southwest of the country bordering the Atlantic Ocean (Fig. 1). It stretches discontinuously along the Cameroonian coastline which measures 402 km from the Equatorial Guinea border to the Nigerian border. The mangrove forest zone extends from the low tide mark to about 30 km inland, covering an area of

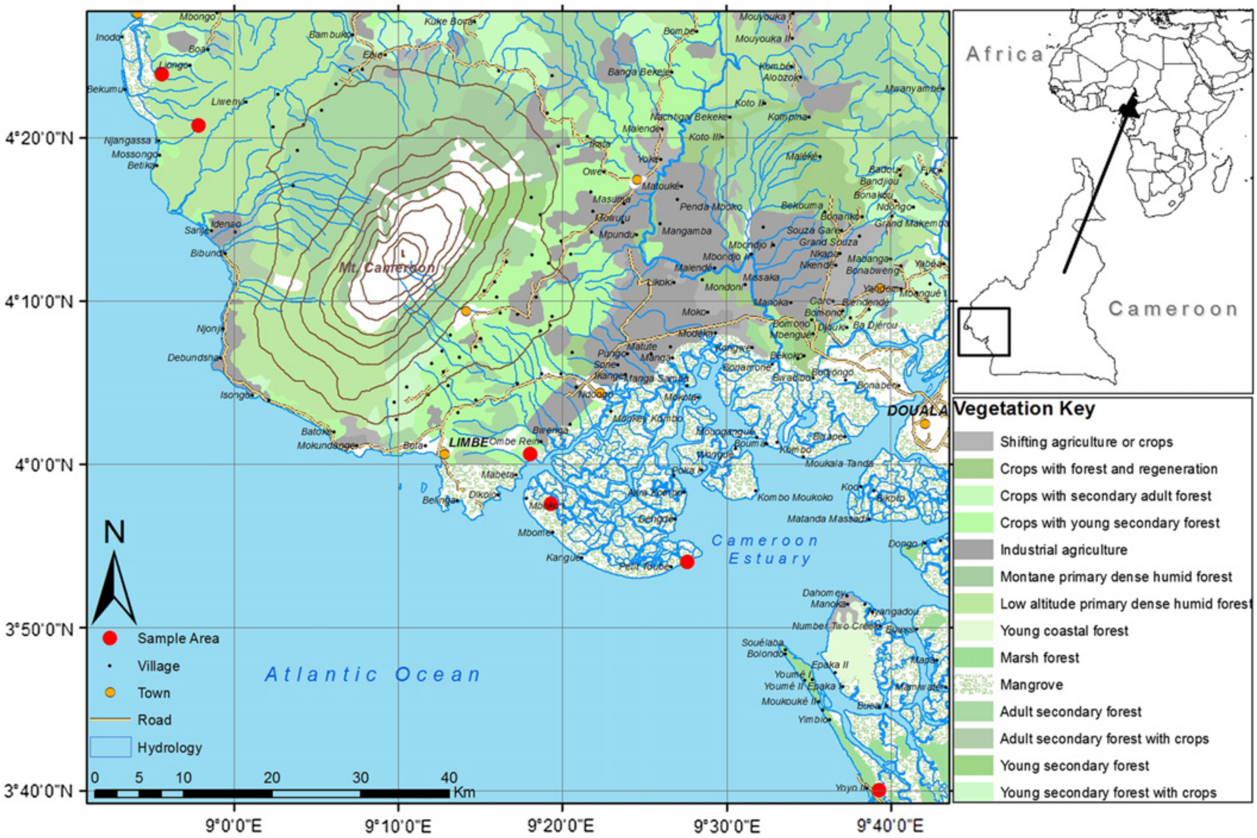

Fig. 1. Location of the study area and sampled sites.

about 1957 km^2. More than 90% of the country's mangrove forests occur in two estuarine complexes bordering the Atlantic Ocean and flanking Mount Cameroon: the Cameroon estuary and the Rio-del-Rey estuary (Ajonina et al., 2004, 2008; Folack and Gabche, 2001; WWF, 2001).

The climate in Cameroon is of the equatorial type, characterized by abundant rains (3000–4000 mm) and generally high temperatures with a monthly average of 24–29 °C. The rainy season lasts for approximately 7 months (April–October), with the most rainfall occurring between June and October (Ajonina, 2008). Tides on the Cameroon coast are of the semi-diurnal type. The amplitude in general varies between 0.3 and 3 m depending on the location, with effects felt within the estuarine complexes. The propagation of waves and ebb-tides is enormous, though poorly known (Folack and Gabche, 2001). The ecosystem is normally inundated by a tidal variation of about 2 m in the rainy season and 1 m in the dry season (WWF, 2001). Historically, settlements within this ecosystem experienced intense floods about once every 5–7 years. However, nearly 15 years ago, the lag time between two successive floods was consistently reduced. At present, intense flooding occurs in the area every year. Peak flood periods occur within the months of July–October (Munji, 2010).

Topographic features along the coast are uneven and include estuaries, deltas, lagoons, and barrier beaches. Soils range from recently deposited, unconsolidated soft dark mud containing silt, clay and peaty clay, to transitional swamps, all of which are associated with different types of vegetation (WWF, 2001). Vegetation is typically mangrove with six species occurring, of which *Rhizophora racemosa* constituting 90% of the total cover, is dominant in the tidal and more inundated areas of the coast (UNEP, 2007). Other forms of vegetation include humid coastal forest species, which are comprised of land-thriving species dotted with mangroves and occur in higher areas.

Human settlements in the mangrove forest zone are typically small (less than 5 km^2) but densely populated, with an estimated average density of about 3000–4000 inhabitants per square km. Population within the area is multi-national (and comprises of Nigerians, Ghanaians, Beninese, Togolese, and Cameroonians) and migratory on a seasonal basis. Most settlements can only be accessed by water, with canoes and motorized canoes being the primary means of transport. Housing is basically wooden, but with varying levels of simplicity. Artisanal fishing is the main economic activity, with activities such as logging of mangrove forests and fish smoking supplementing the fishingi ndustry. Each year, an estimated 75,000 t of fish and shrimp (representing about 60% of the total catch in the country) is smoked traditionally using mangrove wood (Folack and Gabche, 2001).

5. Methods

5.1. Surveys

A reconnaissance survey was carried out once within the study area to better understand the specific characteristics of the settlements, which have not been documented. Physical characteristics including topography, soils and vegetation as well as socio-economic factors such as accessibility and diversity of settlements were noted. This information was subsequently consulted for sampling. Proper data collection spanned a period of 6 months from August 2008 to February 2009 (3 months in the wet season and 3 months in the dry season).

5.2. Sampling and data collection

Six mangrove communities were sampled within the stretch of mangrove forest zone that spans from the Cameroon estuary through the flanks of Mt. Cameroon to the Rio-del-Rey estuary (Fig. 1). This area accounts for approximately 90% of the Cameroon mangroves. Selection of settlements was guided by background information from the reconnaissance survey, expert opinion and exhibition of a range of characteristics within the following criteria: state of mangrove forest cover, elevation above sea level, location of the settlement, annual experience of floods and accessibility. Settlements were grouped according to the state of mangrove forest cover: Group 1 (areas with low mangrove cover: Cap Cameroon and Mboma); Group 2 (areas with moderate mangrove cover: Bekumu and Yoyo); and Group 3 (humid coastal forest: Mabeta and Njangassa). Respondents were randomly selected from a wide range of occupations and within the age range 18–70. This age group was selected because we wanted to source perceptions on issues that have a historical undertone. Overall the selection of respondents was done in a way that ensured representative coverage of the community.

The questionnaire was administered to a total of 200 individuals (Table 1) between August 2008 and February 2009 (3 months in the wet season and 3 months in the dry season). The questionnaire was designed to elicit information on the socio-economic and demographic characteristics of respondents, flood experiences, impacts and coping strategies. Responses were based on perceptions of individuals, which are of course subjective. However, perceptions of communities have been

Table 1
Sampled sites, location, and number of individuals sampled.

Groups	Settlement name	Location (UTM)	Elevation above mean sea level (m)	Number of individuals sampled
Areas with low mangrove forest cover (Group 1)	Cap Cameroon	0549133, 0432015	0	40
	Mboma	536267, 434065	2	30
Areas with moderate mangrove forest cover (Group 2)	Bekumu	487390, 485403	3	40
	Yoyo	0571899, 0403054	0	30
Humid coastal forests (Group 3)	Mabeta	547234, 489895	153	30
	Njangassa	491354, 477234	252	30
Total				200

shown to be very effective in socio-ecological monitoring (Fussel, 2007). Other Participatory Rapid Appraisal (PRA) tools such as semi-structured interviews, and visual assessments supplemented questionnaires. These supplementary tools helped obtain further insights into the impacts of and vulnerability to floods and identify coping responses and adaptive actions in the different communities.

The ground positions of the sampled sites as well as their altitudes above sea level were recorded for subsequent geospatial analysis.

5.3. Analysis

Descriptive statistical analyses were performed to show trends (proportions and graphs) using SPSS version 17. The coordinates of the study sites were superimposed on base topographic maps of 1965 to investigate coastal changes over a period of 43 years using Arcview 9.1 software.

6. Results

6.1. Perceptions of experiences with flooding

In the six studied communities, perceptions on experience with flooding are varied (Fig. 2). Individuals surveyed in all the groups have witnessed and been victims of coastal flooding, with group 1 (i.e., areas with low mangrove forest cover) the most exposed to coastal flooding. Effects suffered due to flooding include house damage, landscape deformation, reduction in fishing yield, reduction in water quality, reduction of access to potable water sources, livestock and farmland destruction, and increased water borne diseases.

6.2. Impacts of flooding on mangrove settlements

6.2.1. The progression of settlements in response to seasonal flooding

A comparison of the present ground position of the settlements with their positions in 1965 revealed that coastal inundation has variably influenced the ground positions of settlements (Figs. 3–8).

Figs. 3 and 4 suggest that the ground positions of Group 1 settlements (Mboma and Cap Cameroon) have shifted inland relative to their positions of 43 years ago, with estimated distances covered being 300 m and 3500 m, respectively. Figs. 5 and 6 suggest that Group 2 settlements (Bekumu and Yoyo) have slightly shifted in the sea-ward direction relative to their positions of 43 years ago, over approximately 175 m and 300 m, respectively. Figs. 7 and 8 suggest that the ground positions of Group 3 settlements (Mabeta and Njangassa) have experienced no noticeable variation over the past 43 years.

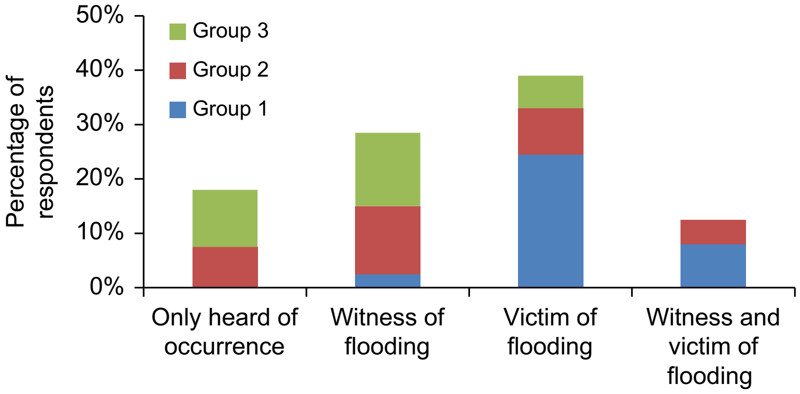

Fig. 2. Perceptions on experiences with flooding.

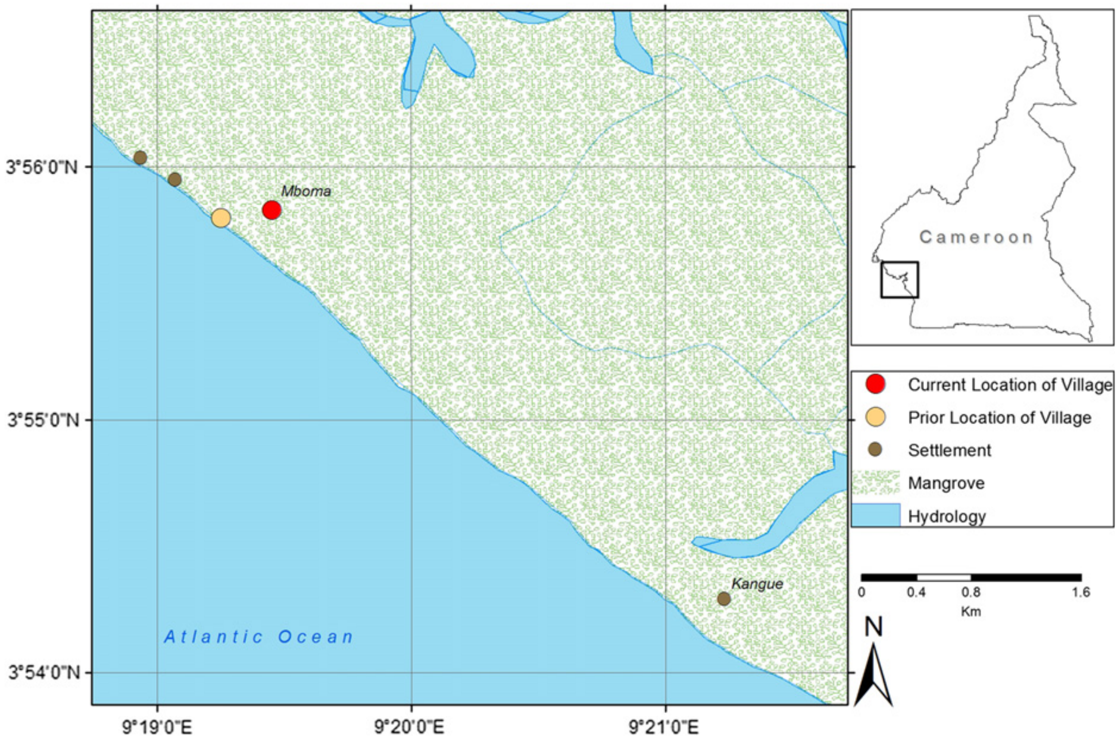

Fig. 3. Settlement progression in Mboma.

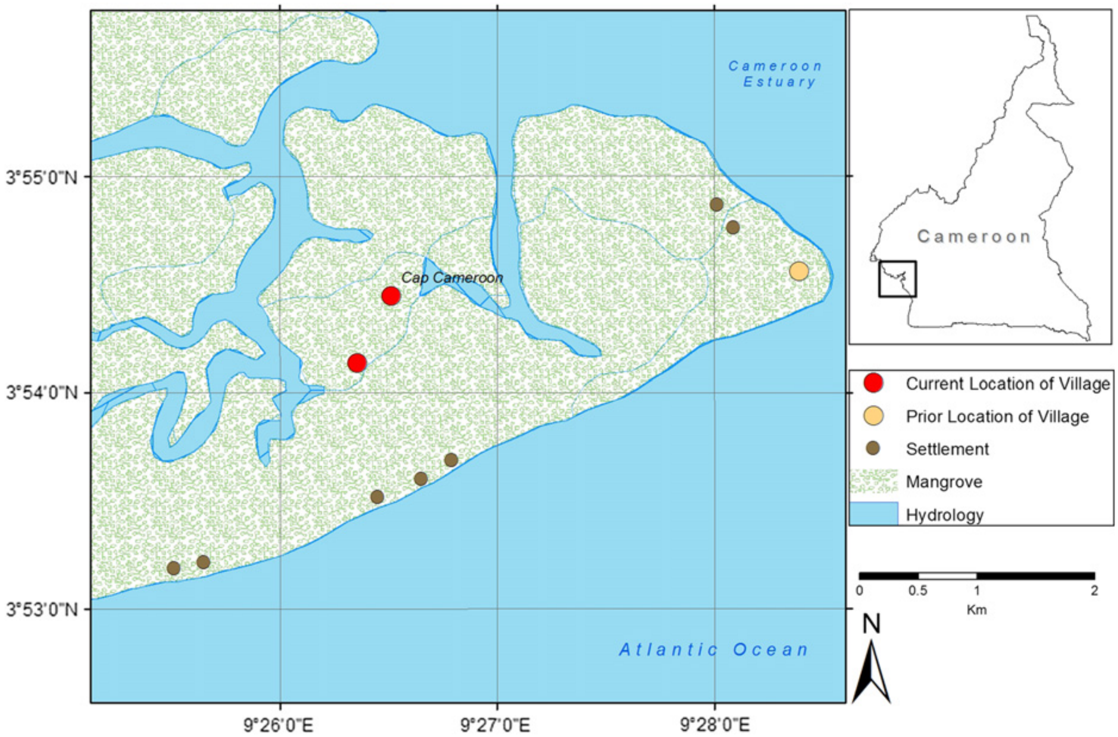

Fig. 4. Settlement progression in Cap Cameroon.

6.2.2. *Mangrove forest destruction*

In general, the mangrove areas are under heavy human pressure. Habitat destruction through human encroachment has been the primary cause of mangrove loss. Clearing of forest for inland relocation and increased exploitation of mangroves during flooding periods has resulted in significant loss of mangrove forest cover (Fig. 9). Measurements suggest that between permanently

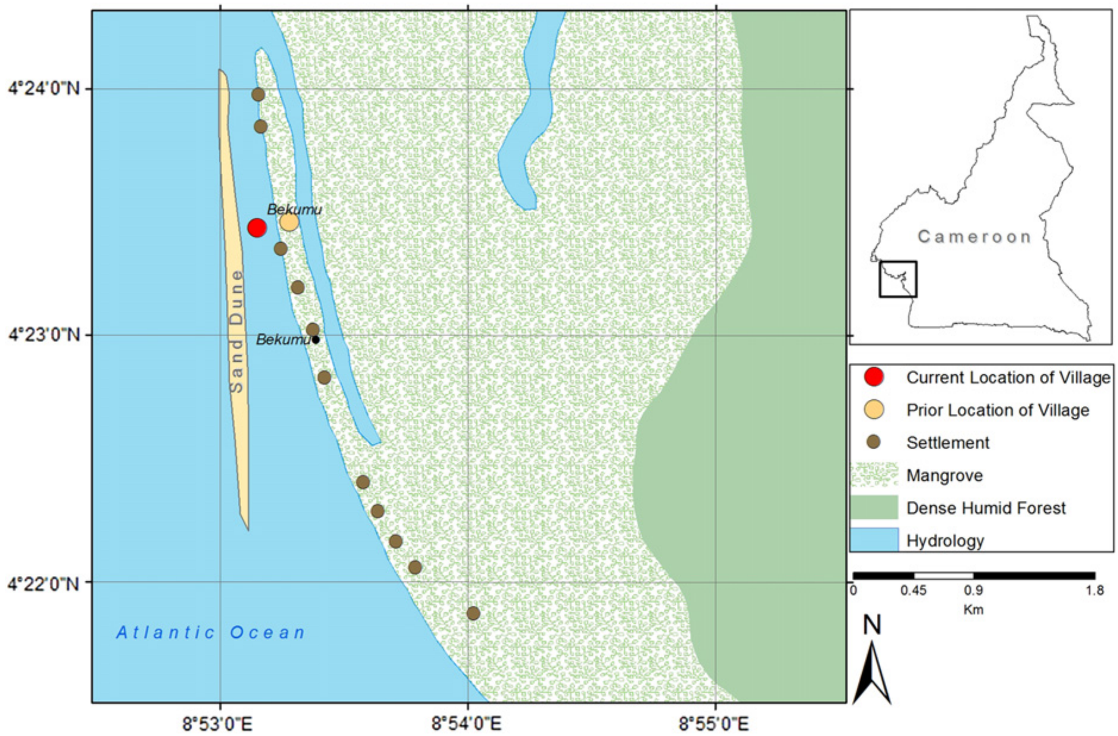

Fig. 5. Settlement progression in Bekumu.

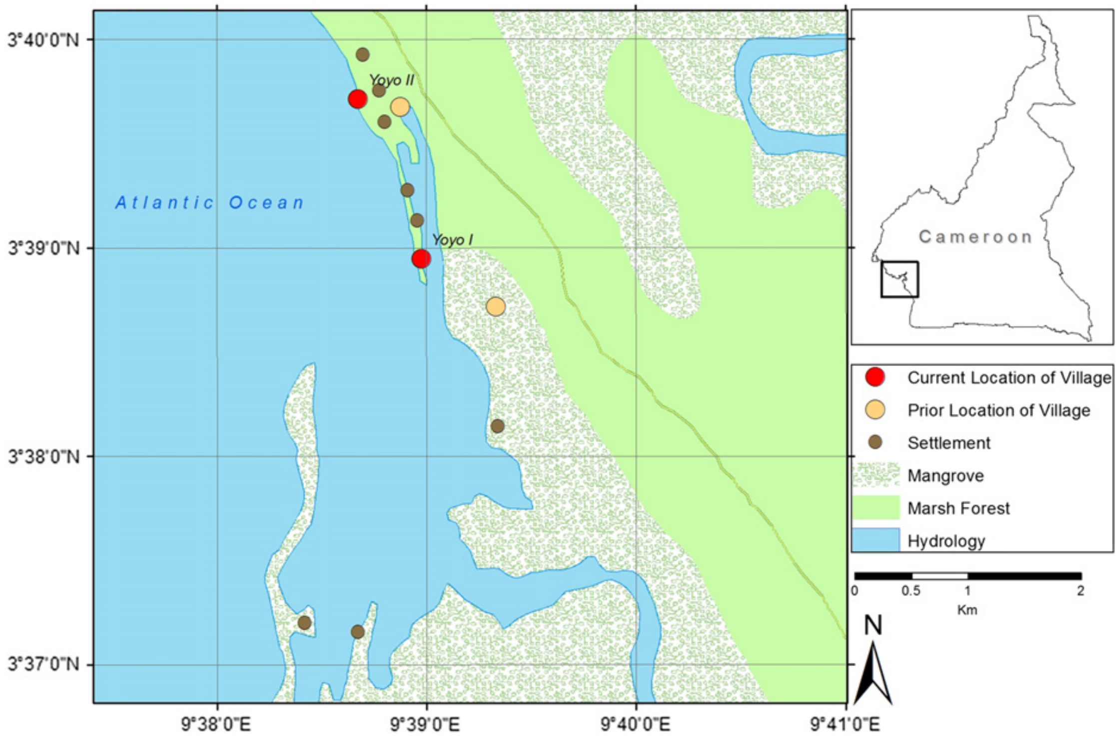

Fig. 6. Settlement progression in Yoyo.

submerged land and current settlement cover, a total of about 989 ha of mangrove forest were lost in cap Cameroon between 1965 and 2008. The loss of mangrove habitats has declined fishery resources, livelihoods, and contributed to biodiversity loss.

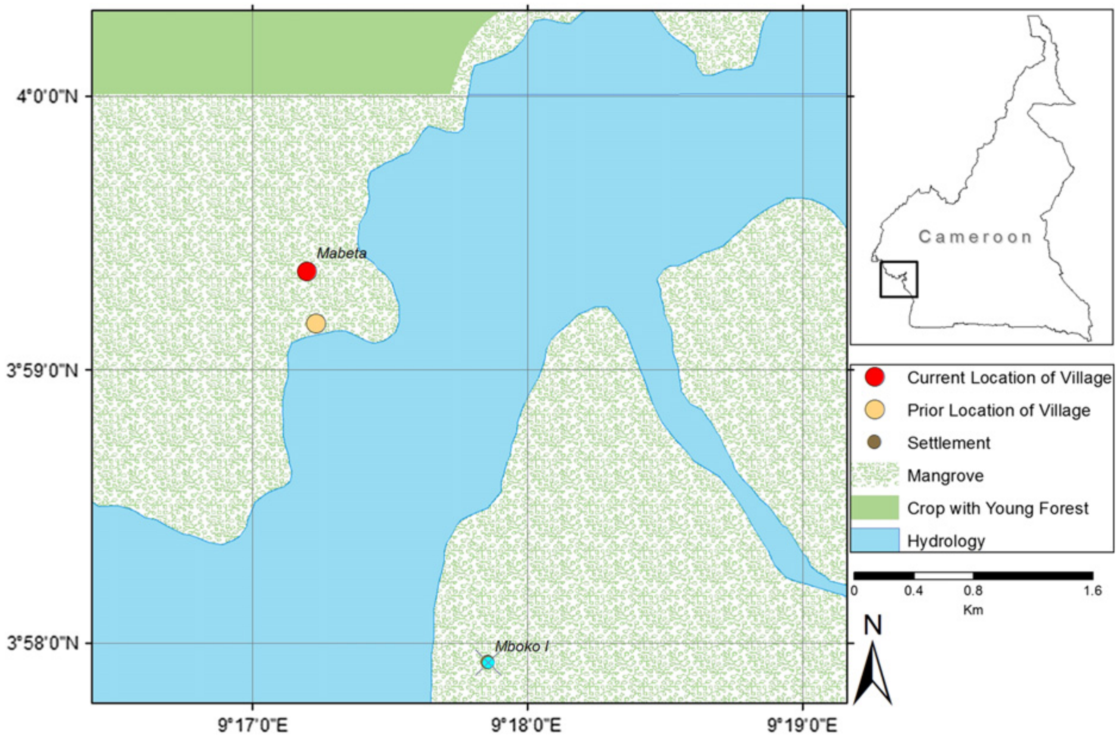

Fig. 7. Settlement progression in Mabeta.

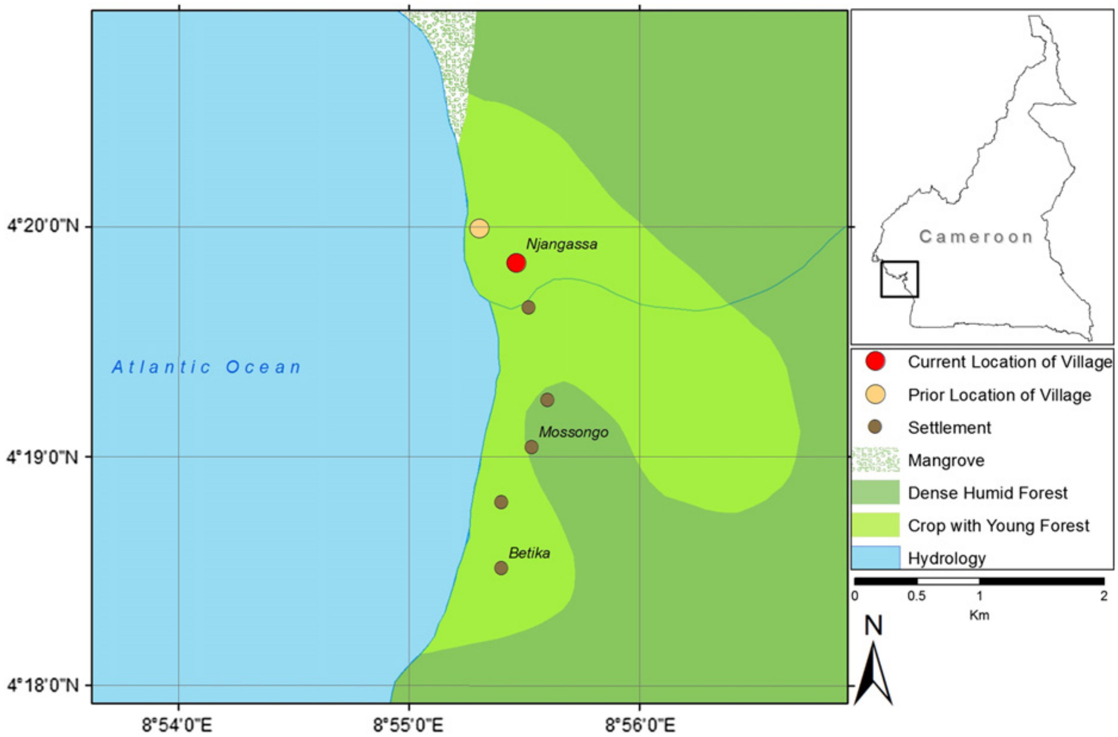

Fig. 8. Settlement progression in Njangassa.

6.2.3. *Increased harvesting of mangrove forest*

Non-Timber Forest Products (NTFPS) within the mangrove forest include mangrove poles and thatch used in construction and fuel wood for fish smoking. Since fish smoking is the only means of preservation of fish used by artisanal fishermen, fuel wood is the NTFP in most demand within the

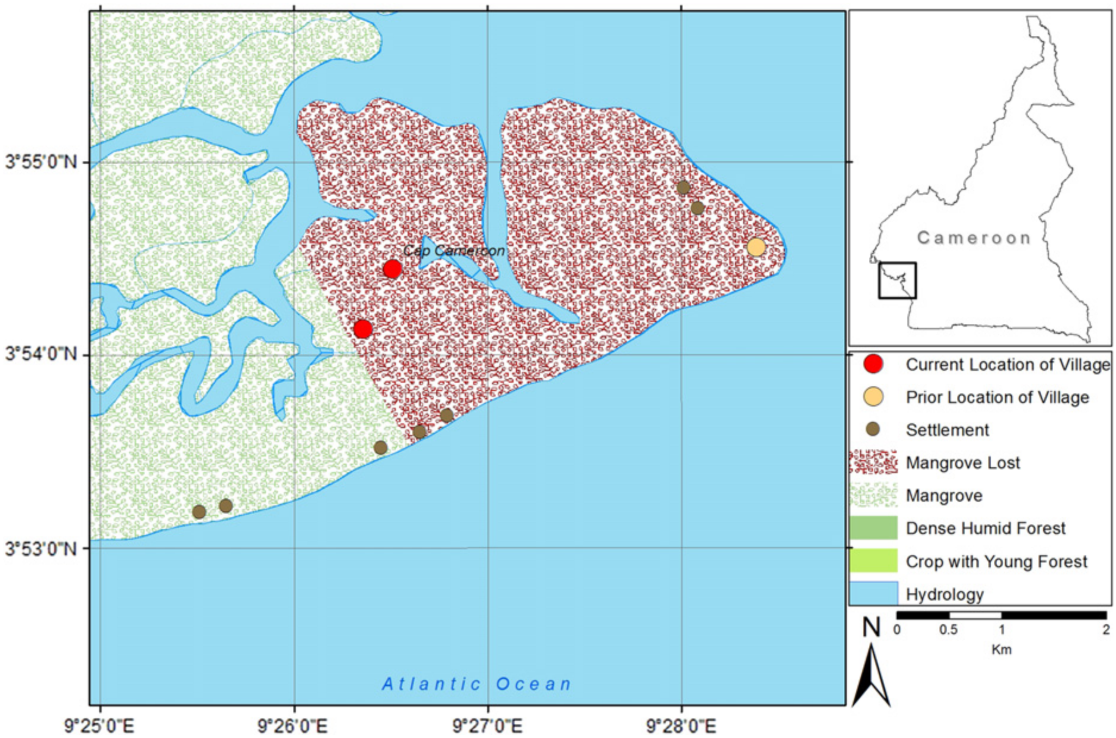

Fig. 9. Mangrove forest deforestation related to flooding.

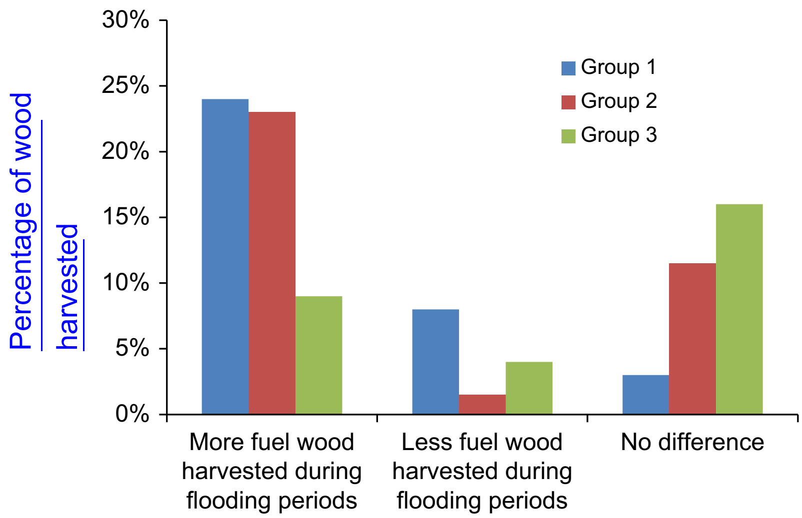

Fig. 10. The relationship between flooding and harvesting of fuel wood.

Cameroon mangroves. Fig. 10 shows the connection between flooding events and changes in harvesting of wood.

The leading perception of individuals surveyed in all the groups (56%) is that seasonal flooding positively influences deforestation for fuel wood. About 30% of the respondents contrarily claim flooding does not affect mangrove harvesting for fuel wood. Increased harvesting of fuel wood during peak periods of inundation is enabled by flood induced creation of water channels in the mangrove forests during high tides, which grants access by canoes to forest areas otherwise inaccessible during non-flood periods. Decrease in fuel wood harvesting during flooding season is said to be due to low fish catch, which presents a disincentive for smoking and hence, harvesting.

6.2.4. *Washing away of mangrove seedlings*

Perceptions of individuals surveyed in all the groups about flood impacts on seedling implantation are as follows: more seedlings are washed out to sea (56%), more seedlings are carried farther inland (40%), seedlings germinate on the spot (4%).

6.3. *Coping with the effects of coastal flooding in mangrove settlements*

In the six studied communities, 94% of the respondents claim that there are no known ongoing flood management measures implemented by administrative authorities/institutions. Community level initiatives for coping with flooding have not evolved beyond the planning stage. Proposed flood management initiatives within the communities include: the building of an embankment, swampland reclamation by planting of eucalyptus, sensitization and training on flood management options, and traditional rites to appease the Gods. Traditional councils of Mabeta and Mboma have forbidden the cutting of mangrove stands and the clearing of tall grass in front of settlements to protect against wind and wave action. The primary coping strategies observed in the study area are based on choice of house type and are: no action, house reinforcement, house design modification and house abandonment. Among perceived barriers to the implementation of individual coping strategies, 49.5% of respondents cited the lack of financial resources, 11% mentioned the lack of technical know-how, 20.5% mentioned the lack of both financial resources and an advisory body, 4.5% identified communication barriers and 0.5% native-migrant misunderstanding

House types ranged from permanent to temporary to makeshift houses, with the choice of building material and design of each house type varying accordingly as shown in Table 2. Make-shift houses were most observed in low areas, especially Cap Cameroon. Temporary houses were the most common house type observed within the study area, while permanent houses were not common.

As depicted in Fig. 11, strategies to cope with the effects of seasonal flood on housing in order of prevalence, include no action (46%), house reinforcements (32.5%), house abandonment (13.5%), and design modification (8%). Group 3 settlements (humid coastal forests) lead in the no action option, Group 3 and Group 2 (areas with moderate mangrove forest cover) respondents lead in house reinforcement strategy, while Group 1 (areas with low mangrove forest cover) respondents lead in abandonment and design modification.

House reinforcement, design modification, and abandonment as adaptive strategies were found to be carried out through a wide range of actions: construction of verandas with sandbags as the most popular reinforcement action (Fig. 12); construction of shelves in houses for suspension of goods during floods, propping of houses on mangrove poles, and swamp refilling with mud/sand as design modification actions (Fig. 13); and dismantling of houses and remounting further inland propped on mangrove poles as is as an action of house abandonment (Fig. 14).

Table 2
House types in the mangrove forest settlements.

House type	Building materials	Distinctive feature
Permanent houses	Walls: Cement blocks/wood Floor: Cement Roof: Aluminum sheets	Well-constructed veranda, raised floor levels.
Temporary houses	Walls: Wood and mangrove poles Floor: mud Roof: aluminum sheets/thatch	None/temporary verandas or improvised verandas built with sand-filled bags.
Makeshift houses	Walls: wood and mangrove poles Floor: above ground wooden floor (suspended 0.5-1 m above the ground, on mangrove poles) Roof: aluminum sheets/thatch	House is suspended above-ground on mangrove poles.

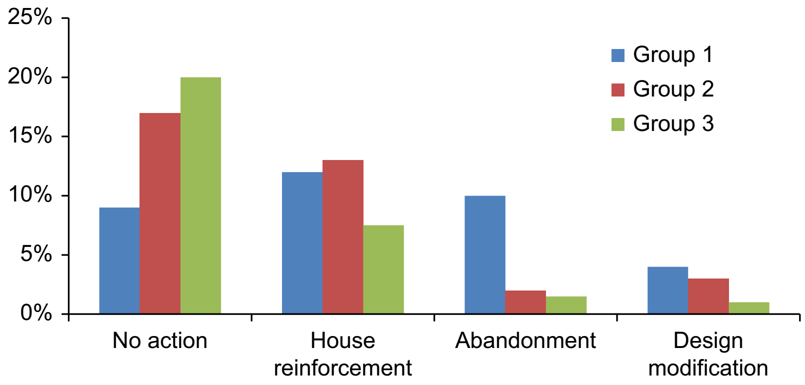

Fig. 11. Adaptive strategies to the effects of seasonal flooding on housing.

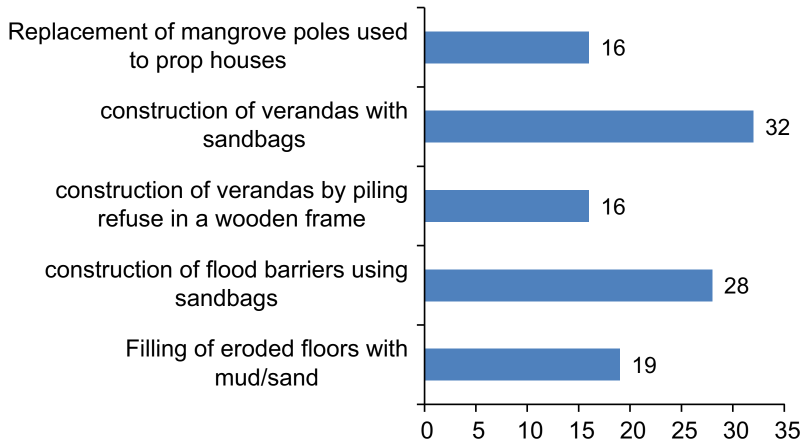

Fig. 12. Actions related to house reinforcement.

7. Discussions

7.1. Floods, perceptions and impacts

The location of the three groups of settlements was shown to have evolved variably or not at all; Group 1 (areas with low mangrove forest cover: Cap Cameroon, Mboma) settlements have shrunk inland, Group 2 (areas with moderate mangrove forest cover: Bekumu, Yoyo) settlements have expanded in the sea-ward direction, while the coastal limits of Group 3 (humid coastal forests: Mabeta, Njangassa) settlements have not changed. Correspondingly, the inhabitants of the different groups of settlements have different experiences with flooding, and perceptions of flood impacts. The physical location and level of protection of the different groups of settlements together determine their level of exposure and sensitivity to flooding. Differences in exposure and sensitivity together with differences in the responses of the settlements to flood events determine the nature of flooding impacts on their coasts and hence vulnerability. For example, depending on the unique characteristics of each settlement's coast, access of tidal surges to the settlements is either enhanced or hampered, resulting in erosion and partial/total inundation, or sediment deposition, respectively. This supports the conclusion of Forner (2006) that moderated by adaptive capacity; vulnerability is a function of the exposure and sensitivity of a system to a climate change effect.

Responses to flooding were shown to vary between settlements irrespective of similarities in the level of coastal protection (mangrove cover) or elevation above sea level. Settlements with the same elevation above sea level but with different degrees of mangrove protection were found to have different responses to flooding. For example Cap Cameroon (Group 1) and Yoyo (Group 2) are both at sea level (± 0 m), yet Cap Cameroon has retreated 3.5 km inland while Yoyo has contrarily shifted

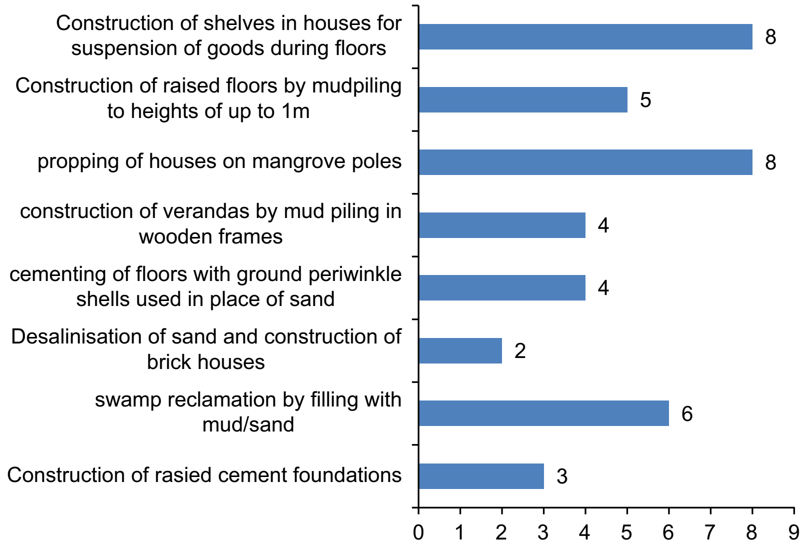

Fig. 13. Actions related to house design modification.

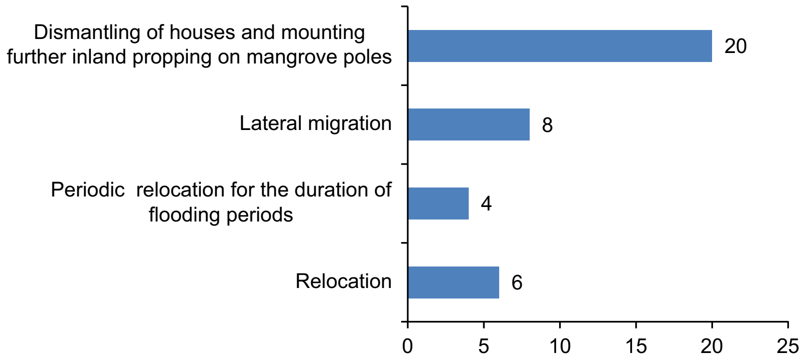

Fig. 14. Actions related to abandonment.

sea-wards. Similarly, Group 1 (Cap Cameroon and Mboma)and Group 3 (Njangassa and Mabeta) settlements which have in common low levels of mangrove protection have strikingly different changes in their coastlines. Cap Cameroon and Mboma (Group 1) have significantly retreated inland while the positions of Njangassa and Mabeta (Group 3) have not changed. This phenomenon could be explained by the fact that Cap Cameroon and Mboma lie at 0 m and 2 m above sea level respectively, as opposed to Mabeta and Njangassa which are both more than 150 m above sea level. Also, the former locations have silt or sand as their top-most sediment layers, while the later locations have laterite-rich soils. These findings draw parallels with South and Southeast Asia, which are particularly vulnerable to flooding due to their concentration of low-lying populated deltas (Brenkert and Malone, 2005; Nicholls et al., 1999). Therefore, mangrove forest cover, and elevation above sea level are equally important ~~as~~ factors influencing vulnerability of settlements.

Perceptions of flood impacts in settlements indicate that flooding affects settlements, albeit differentially between the various groups. With intensification of flooding as an expected consequence of the ever-increasing deforestation of mangroves (Asangwe, 2006) as well as climate change (IPCC, 2007), anticipated future impacts include: (1) the occurrence of flooding in presently unaffected settlements and its intensification in affected settlements and (2) devastation within settlements resulting in haphazard migration and eventually conflicts between old and new settlers as was recently the case in the Northern parts of the country (Ayonghe, 2008), with serious socio-economic impacts. In addition, the probability of negative outcomes will likely increase if management efforts are not intensified. Given the absence of adaptive capacity building, inadequate adaptive actions may result in resource degradation under adverse conditions, especially deforestation, and further exacerbate the effects of flooding. Adger et al. (2005) have shown that ineffectual adaptation exacerbates the effects of climate change.

Permanent inundation of occupied land and resulting inland retreat of settlements to cope with the advancement of the sea necessitates the clearing of mangroves to create land for relocation. The progressive loss of about 989 ha of mangrove forest cover in Cap Cameroon over 43 years has serious implications for the local forest resource base and biodiversity, particularly fish, which spawn in the mangroves (Spalding, 1997; Asangwe, 2006). This is contrary to Gilman et al. (2008) who claim that managed retreat, sea level rise could present an adaptation opportunity for inland migration of mangroves.

Community perceptions also suggest that coastal flooding promotes the exploitation of NTFPs like fuel wood, through the increased access by canoe to areas otherwise inaccessible during non-flood periods. Feka et al. (2009) and Feka and Ajonina (2011) corroborate that July and August which are peak flood months in coastal Cameroon, is the primary mangrove harvesting period. Fuel wood harvest during this time increases because high tides present a transportation opportunity by canoe for women and children not strong enough to transport fuel wood otherwise (Feka and Manzano, 2008). Flooding therefore promotes the intensification of deforestation in the Cameroon mangroves. Although, some respondents mostly of Group 3 claimed flooding makes no difference to the quantities of fuel wood harvested, this discrepancy is due to the availability of alternative fuel wood sources in these settlements. The availability of such alternative resources has been shown to reduce dependency on mangrove forests (Feka and Manzano, 2008).

In addition to direct loss of mangrove forest cover, flooding can prevent seedling implantation, potentially resulting in further mangrove degradation. This understanding is based on community perceptions in this study. This suggests the need for the further investigation of flood–mangrove interaction, particular given the potential intensification of flooding under a changing climate.

7.2. Coping strategies and coastal flooding

Settlers of the Cameroon mangrove forest area have developed numerous coping strategies ranging from the type of houses lived in, to flood preparation and management measures. The type of houses prominent in each settlement are generally reflective of the perceived level of vulnerability of occupants. Makeshift houses are highly appropriate in high flood risk settlements where they can easily be dismantled and moved inland in the event of floods. Temporary houses are found in all settlements but are in some instances inappropriate given that they are mounted on stilts in muddy ground. Nonetheless, preference of this house type is possibly due to the facts that its building materials are cheaper, and most of the inhabitants are seasonal settlers who are reluctant to invest in the construction of more durable houses. The permanent houses that were observed are owned by old settlers or natives, and occur mostly within the group 3 settlements located at a higher elevation. Irrespective of type, it was observed that houses are built in tight clusters. Although this is not an intentional adaptive strategy in the area, it has been effective in minimizing flood effects in the Sabah floodplains of Malaysia.

Retreat as a coping strategy was common in Group 1 settlements (Cap Cameroon and Mboma) only. Managed retreat has been effective as a community-level flood management strategy in other areas, ensuring both economic and ecological benefits in the long run (Gilman et al., 2008). However, due to the uncoordinated manner in which retreat is carried out within Cameroon's mangrove settlements, the frequency of movement necessitates the clearing of forests at a faster rate than is sustainable for forest regeneration. In addition, because of the presence of a dense network of creeks that limits available land for inland retreat, this strategy may eventually increase vulnerability to flooding. Periodic migration continues to be employed by the mangrove settlements, however, as an adjustment that enables them to avoid flooding and hence, to reduce property loss. This strategy has been very effective in flood management for the urban poor (Fogwe and Lambi, 2001).

In situ coping strategies to flood impacts on housing were numerous and varied, largely reactive, and specifically geared at minimizing flood effects. The predominance of a specific coping strategy within a settlement was generally reflective of the intensity of flooding experienced in the settlement. Irrespective of expected efficacy, however, the choice of strategies could be influenced by other factors such as finance. Cultural background could also have an influence on people's perceptions and behaviors in response to hazards. For example, the different cultural backgrounds of two people could influence the decision of one to raise their house on poles and of the other to raise their floor by mud-piling. This is typically the case in situations of trans-boundary migrations; natives and new settlers have different perceptions of hazard, as well as coping strategies. Where adaptive actions are found to be inappropriate or carried out at a scale that does not minimize flood effects, the prevalence of these strategies may actually reflect an inability to adapt. Adger et al. (2004) corroborates that an adaptive action is only successful if it meets the objectives of adaptation and does not affect the ability of others to meet their adaptation goals.

Results also reveal that within the coastal mangrove settlements that were surveyed, all on-going adaptive actions are carried out at the individual level. This is contrary to Adger et al. (2004) who claim that coastal management schemes yield individual benefits only if efforts are collective. While, individual adaptive measures have in some cases succeeded in making the effects of flooding negligible, there is a limit to the extent of broader community resilience that can be attained through stand-alone efforts by individuals. This is due to the fact that limited by financial, technological, and educational constrains, augmentation of current coping strategies is hindered. Coping strategies that are employed are hardly commensurate with the rate and magnitude of change being experienced, and therefore are no longer seen as useful. Adger et al. (2004) corroborate that coastal management schemes yield individual benefits only if efforts are collective. Furthermore, some adaptive actions while effective are resource-inefficient, and potentially translate pressure from one sector to another, or proliferate into secondary effects. Haddad (2005) confirms that low adaptive capacity yields ineffectual adaptive actions that exacerbate effects.

8. Conclusion

Coastal flooding constitutes an additional stress to already existing pressures within the coastal mangrove areas of Cameroon. Wood harvesting, conversion of mangroves for agriculture, and bio-fuel plantations are other important drivers of mangrove forest change which have proven to be very difficult to manage. Even more important as a driver for mangrove forest change is accelerated coastal development responsible for the localization of over 60% of industries along the coasts, especially 2000 and 2006, a period that coincides with large oil discoveries in the region. The loss of mangrove habitats has contributed to declined fishery resources and livelihoods, and biodiversity loss. Future management approaches should prioritize the elaboration of policies that address the risks of declining mangrove ecosystems in Cameroon. This will require focus on adaptive strategies, reviewing existing coastal and marine ecosystem policies, and development and implementation of an integrated coastal management strategy for the region. In addition, institutional and educational guidance of communities will serve to harness the wealth of knowledge embedded in current adaptation efforts and determine its viability under changing climate risks. Special efforts will be necessary to enable resilience building among communities and help them to more effectively and sustainably cope with current and future climate risks. A combination of interdisciplinary tools such as policy, education, research, and financial measures should be applied to mitigate flooding, improve adaptation to flooding, and remove incentives that drive the destruction of coastal protective features such as mangroves.

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