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# ASCRIBING THE CAPRICIOUS WEATHER THESIS TO THE UNPRECEDENTED JULY-SEPTEMBER 2022 FLOOD HAZARDS IN THE KUMBA AND MUTENGENE-LIKOMBA AGGLOMERATIONS OF THE SOUTH WEST CAMEROON COASTAL PLAIN OF CAMEROON

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## ABSTRACT

Recurring flood scenarios are globally, the most endemic, ubiquitous and dramatic natural hazards especially on low-lying and steep sloping areas. The area space covered by the settlements of Kumba, Mutengene and Tiko have these characteristic landscapes and flooding events common but those of July to September August to 2022 were not only record breaking but somewhat enigmatic in nature. This study sought to make an in-depth examination of probable triggers of the hydroclimatic catastrophe. The study adopted the mixed research design combining both quantitative and qualitative techniques. Primary data on the dimension of the flooding scenarios, the drivers were obtained through empirical research methods of direct and indirect field observations of affected areas. Daily, monthly and annual climatic data were sourced from NASA satellite database, and analysed to obtain temporal rainfall intensities and distribution patterns. Change detection of landcover and land uses were established through GIS analysis of satellite images between year 2000 and 2022. Impacts of the flood events were obtained through an exploratory survey of the flood impacted zones. The results revealed the principal trigger mechanism of the cataclysmic floods of July and September 2022 to be the disruption of the natural balance of the landscape linked to combined effects over the years, of intensifying high rainfall concentration within fewer months of the year, and the heightened vulnerability of the landscape due to uncontrolled land cover and land use mutations that have coerced anthropic colonisation of natural water course ways, to the extent that indigenous adaptation measures as raised foundations and sand bag embankments were dwarfed by the flood waters.Far reaching consequences registered were destruction of communication lines, infrastructural facilities, arable and pastoral farmlands and landscape spoliation by landslides. The recommends proper land use planning and improvement of drains systems as the sustainable preventive panacea to such a situation.

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# INTRODUCTION

Floods are the most documented environmental hazards that often result in irreparable devastations within vulnerable zone. This paper starts with a summary review of existing literature, proceeds with the problem statement and the study area, elaborates the research procedures, presents the results and findings, discussions, conclusion, acknowledgements and references.

### Survey of Literature

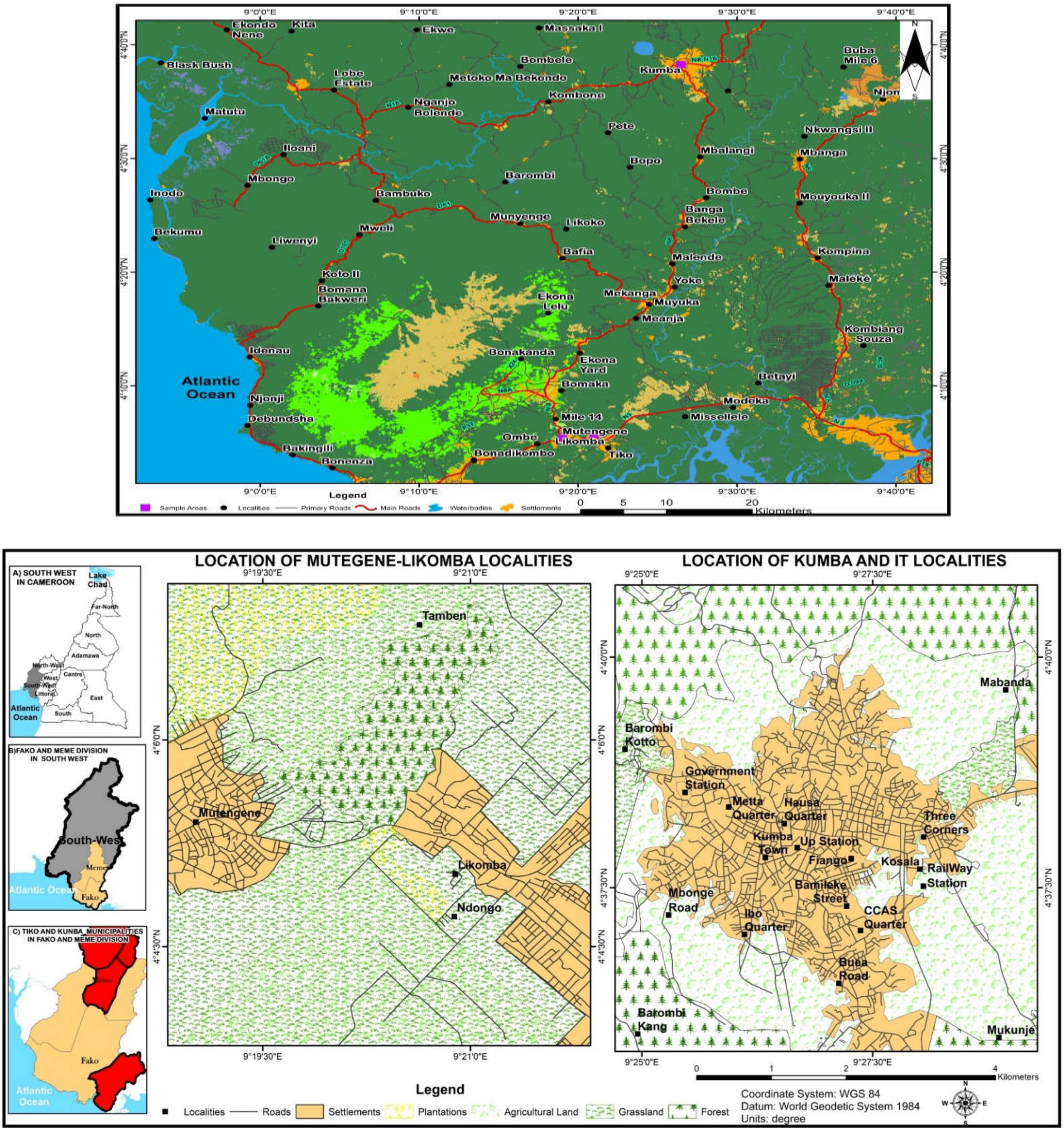
A plethora of literature exist on the flood hazard story. Some are reviewed here to streamline the present paper in this research domain. Globally, floods are responsible for the considerable and increasing economic and social losses Kundzewicz*et al.* (2014). in Canada floods are happening more frequently and are more spread under a rapidly changing climate, Whitfield (2012) and Nastev and Todorov (2013). Aderogba (2012), noted that the causes of most urban floods were related with indiscriminate dumping of refuse, encroachment upon and poor channelisation of drainage coupled with the unethical human activities along flood plain. The Canadian Disaster Database (2016), noted that, between 1990 and 2015, 141 flood disasters were recorded in Canada, which were responsible for killing 21 people, displacing 215,141 people, and causing damage costing an estimated CAD $7.9 billion. In the United Kingdom, annual flood damage is estimated at $1.1 billion and expected to rise to as much as $27 billion by 2080 under a worst-case climate change scenario, with no additional adaptation measures. Garrett (2011), noted that in Australia, between December 2010 and January 2011, Western Australia, New South Wales, Victoria and Queensland experienced widespread flooding that resulted in 37 lives lost and a total cost of over AUD $ 30 billion to the Australian economy. Shrubsole (2013), stated that the standard approach to flood risk management (FRM) amongst developed nation has often been the adoption of resistance-based strategies. He further stressed that floods could also be controlled through the improvement of housing structures, laws and regulation as well as maintaining the natural environment. According to Fombe *et al.*, (2015) and Philemon, (2022) the intermittent torrential rains in the South west region led to the overflow of small streams within the city and triggered several voluminous torrents from highland areas towards the coastal communities making its infrastructure very vulnerable to flood incidences. They also made mentioned that the peak rainfall experienced in the rainy season stimulated floods within the city. Balgah and Nkemasong (2018), concluded on the triggers of endemic urban floods as being largely the hand of man than the work of nature. Kumba, Mutengene and Tiko areas are typical third world urban centres with rapidly growing populations that face numerous challenges that presently are being compounded by widening and deepening hydroclimatic linked disasters as floods and landslides, that requires special research attention at the moment. Kumba, Mutengene and Tiko areas are typical third world urban centres with rapidly growing populations that face numerous challenges that presently are being compounded by widening and deepening hydroclimatic linked disasters as floods and landslides, that requires special research attention at the moment.

***The Problem statement:*** Kumba, Mutengene and Tiko are communities within the coastal lowlands of Cameroon lying within 100km from the Atlantic Ocean. Being resource and opportunity rich areas, very rapid population growth has installed, with consequent sprawling of settlements into lands hitherto considered marginal for anthropic activities. These settlements have spread over undulating landscapes with Kumba on a stepped tableland, Mutengene on the slopes of Mount Cameroon and Likombaa piedmont on the Tiko plain. The mountain equatorial climate is characterised by annual rainfall totals of about 2000 mm, with a higher proportion coming between June and September months. The geo-climatic traits of the areas make them vulnerable to hydro-geomorphic hazards dominated by recurrent flood incidences and sporadic landslides. For decades, these phenomena have been recorded within these communities at scales considered normal. The 9July 2022 in the Mutengene-Likomba area and 3rd to 4th September 2022 in Kumba, marked the peak moment of a flooding season. Flood waters struck record high levels, spread to hitherto non-vulnerable areas and putting to shame all existing adaptations and flood control measures. The months of July to September 2022 changed the mindset of the inhabitants about floods and the dates remain a nightmare to them. The unprecedented character of the July-September 2022 flood episodes within these coastal areas, reemphasised the need to continually dissect the floods story for a better understanding of the root causes of such a cataclysmic phenomenon so as to suggest more sustainable preventive measures.

***The Study Area:*** Figure 1 shows that the area under study covers three key settlements on the coastal lowlands of Cameroon. Kumba (latitude 4° 38′00″ N and longitude 9° 24′00″ E) Meme Division lies inland and while Mutengene (latitude 4° 5′26.10″ N and longitude 9° 19′7.56″ E) and Likomba (latitude 4° 5′15.18″ N and longitude 9° 20′25.01″ E) in Fako Division are nearer the Atlantic coast. These three settlements are road junction towns with national highways, N8 and N 3 converging at Mutengene while N8 and N16 converge on Kumba. Additionally, Kumba is TRANSCAM railway terminus. Figure 2 shows the spatial spread of the study areas. The Mutengene-Likomba zone extends from latitude 4°4′30″ N to 4°6′00″ N of the Equator and longitude 9°18′00″ E to 9°21′00″ E of the Prime Meridian. This gives a surface area of 33.21 $km^2$. The average relief varies from 243 m in Mutengene to 76 m in Likomba. Kumba covers the area between latitude 4° 36′00″ N and 4° 39′00″ N of the Equator and longitude 9° 24′00″ E and 9° 28′00″ E of the Prime Meridian. It covers over 286 $km^2$ and has an average altitude of 240 m above sea level. The high route network connectivity, coupled with the great endowments (fertile soils for agricultural development and commercial linkages amongst others) gives these areas high demographic potentials. The high population concentrations heighten the vulnerability potential of the population to any natural disaster occurrences notably floods that are usually very extensive in scale. The greater part of Kumba spreads over an extensive low plateau dissected by the valleys of main streams (Kumba, Kake and Mambanda) and their numerous tributaries that flow from the Barombi Mbo volcanic cone. Mutengene is a stepped tableland on the slopes of Mount Cameroon while Likomba is part of the Tiko plains that constitute the piedmont zone and a receptacle of huge volumes of overland flow from the surrounding steep slopes during storms. Mutengene is drained by two main streams while Likomba by the Likomba Stream, all descending down the slopes of Mount Cameroon.

***Methods and Tools:*** This observational study adopted the mixed research designing, combining the qualitative and quantitative methods. Two reconnaissance surveys to the affected areas were conducted immediately after the flood events, from the 10th to 12 July 2022 for the Mutengene – Likomba Zone and 5th to 7th September 2022 in the Kumba area. These were to identify and map out highly impacted zones for detailed investigations. To enhance efficient primary data collection from field observations and measurements, tools and instruments as the GPS, Digital Cameras, measuring tapes, questionnaires and interview guides alongside recordings were used. Through field observations, high flood incidence areas were located and the dimension of the landscape scarification effects were measured with tapes. The GPS was used to pick up the coordinates for georeferencing and digital cameras took still pictures of the effects. These built up the requisite data for designing the vulnerability and flood impact maps. The stratified systematic sampling technique was used to administer structured questionnaires to 50 respondents in the affected. The respondents were largely victims and they provided an eyewitness account on the likely triggers and the magnitude of the impact of the particular flood incidence. The responses were coded and frequency tables built up for quantitative processing. Direct interviews of local authorities provided supplementary qualitative data that reinforced the victims and eyewitness accounts on the flood disaster events.

Data to establish the flood trigger mechanisms were obtained from multi sources and techniques. The landscape change detection was established through land use- land cover (LULC) evolution through the use of GIS to analyse satellite images at two-time scales- 1990 and 2020. This provided information that permitted the assessment of man's contribution to the July-September 2022 flood dilemma. Rainfall data on the daily, monthly and annual temporal scales were carted from the NASA climate data base. These three categories of rainfall data collected were: the daily rainfall data from 1st July to 5th September 2022 to establish the daily variability; rainfall daily occurrence since January 2022 to establish the monthly rainfall variability; and monthly rainfall for Kumba from January 2015 – 2022 to establish the inter-annual rainfall variability for the study area. These data were processed into mean daily and monthly rainfall intensities, and the rainfall frequency as well as the percentage of normal rainfall concentration ratios were established. The empirical formulae used for these calculations were the following:



Source: Extracted from Topographic Maps and Satellite images

Figure 1. Location and spatial delimitation of the study sites

- **Mean monthly rainfall intensities (MMRI)** $=\frac{Total\ monthly\ rainfall\ (mm)}{number\ of\ rainy\ days}$ = mm/month
- **Mean daily rainfall (MDR)** = $\frac{Total\ rainfall\ for\ the\ season\ (mm)}{Number\ of\ rainy\ days}$ = mm/day

Note: Rainfall days are used for calculation of rainfall intensities because hourly rainfall data were not available.

- **Rainfall Frequency (RF):** = $\frac{Rainfall\ at\ a\ moment\ in\ time\ (mm)}{Total\ Rainfall\ for\ the\ whole\ period\ (mm)} X\ 100$ .

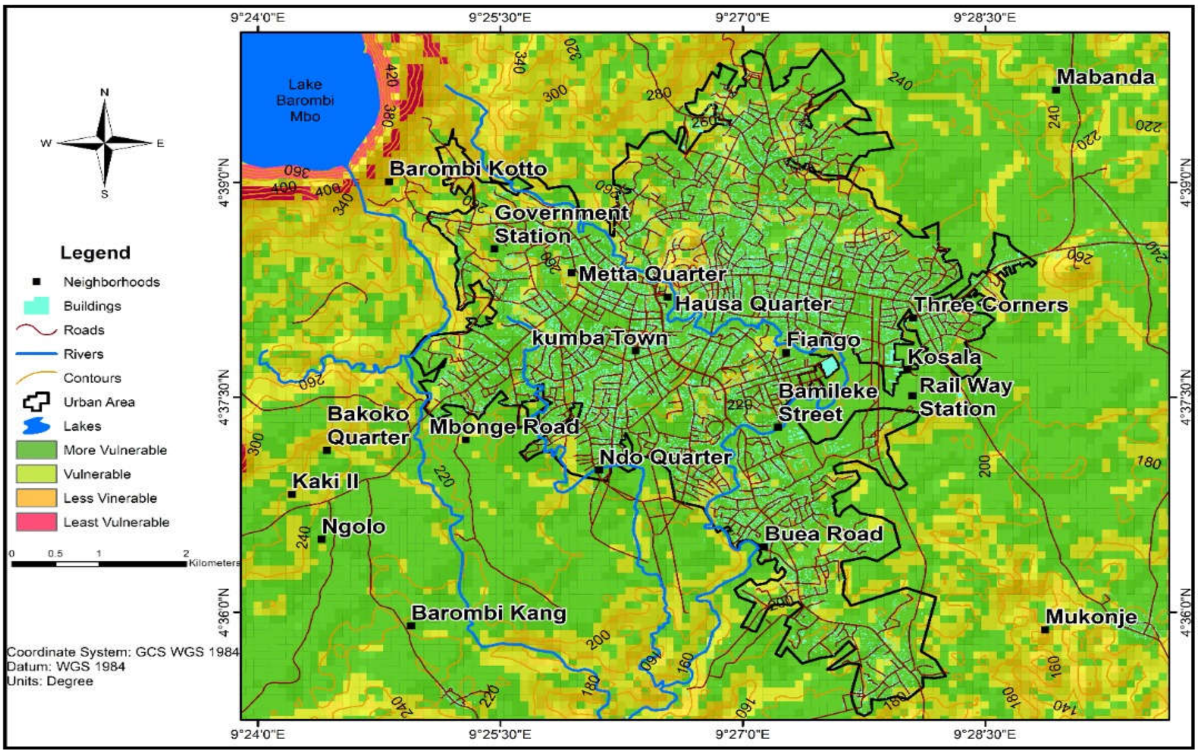
This gives the distribution of rainfall (rainfall concentration ratio) across the period under consideration (isomers). The values of the isomers here are derived by *expressing the rainfall amount of point as a percentage of the total amount of rainfall across the period.* This is modification of the approach advanced by Gregory (1964) since it is an easier quantitative method and more realistic than Gregory's approach.The interpretation of the results is guided by the following scale:< 75% indicates below normal precipitation; 75% - 125% normal precipitation; and >125% above normal precipitation. Ethically, adequate barrier measures were integrated into the field activities since the COVID-19 pandemic and cholera outbreak in the study zones were severe. Furthermore, the express concern of all those snapped and interviewed was obtained in advance.

# RESULTS

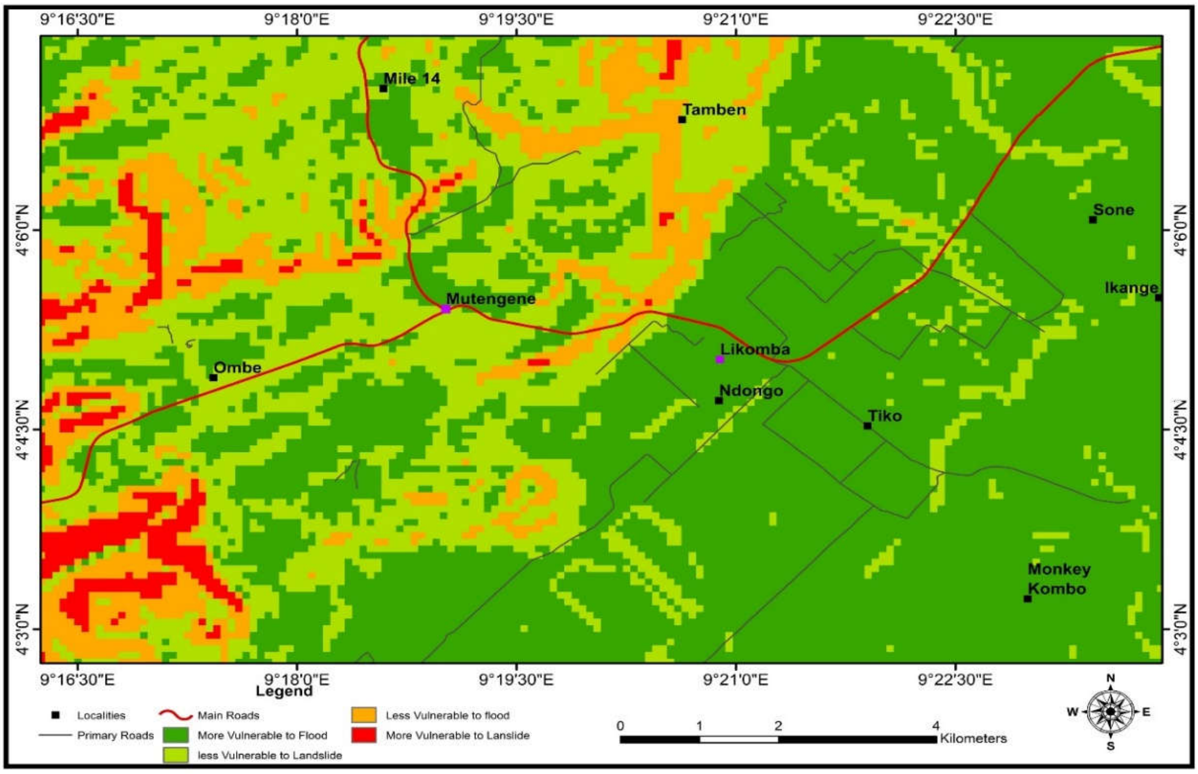
This presents the findings on the spatial dimension, impacts and the trigger mechanisms of the floods.

***Spatial Dimension and vulnerability:*** This brings out the areas highly affected by the flood, the characteristics of their landscape in terms of land cover (slope gradients) drainage systems and valleys and the land use characteristics as infrastructure design patterns as well as economic activities. Through this the vulnerability of the areas to flood disasters was established. One of the peculiarities on the spatial occurrence of the July to September 2022 floods in Kumba and the Mutengene -Likomba areas was that though the traditional flood prone zones were affected, the floods transcended them and dissected new flood niches on the landscape. These areas affected by the July-September 2022 floods in the Kumba and Mutengene-Likomba agglomerations are shown on Figures 2 that present the flood vulnerability maps of the area.

The map reveals that most of the flood affected areas during the September $3^{rd}$ 2022 floods in Kumba were largely the traditional flood sites located along the flood plain of the Kumba Stream. The most impacted areas were Nkamlikum Quarters, Lumumba Street and Kumba Town areas Malabo Quarters (polytene Quarter),Alfred Saker Primary School Field and parts of Buea Road around Cow Fence and Paradise Street as noted in earlier studies by Fogwe&Ngum(2016) and Balgah and Nkemasong (2018). The September 2022 floods reveal many new flood niches in the city such as Down Hill Mbonge Down Hill Mbonge Road (Full Gospel and Sustenance Street), Fiango (New Layout, Wilderness Farm Road Street and below CCC Kumba) and Meta Quarters and neighbouring zones to the valley separating Fiango and Kosala.



**a) Flood vulnerability areas of Kumba**

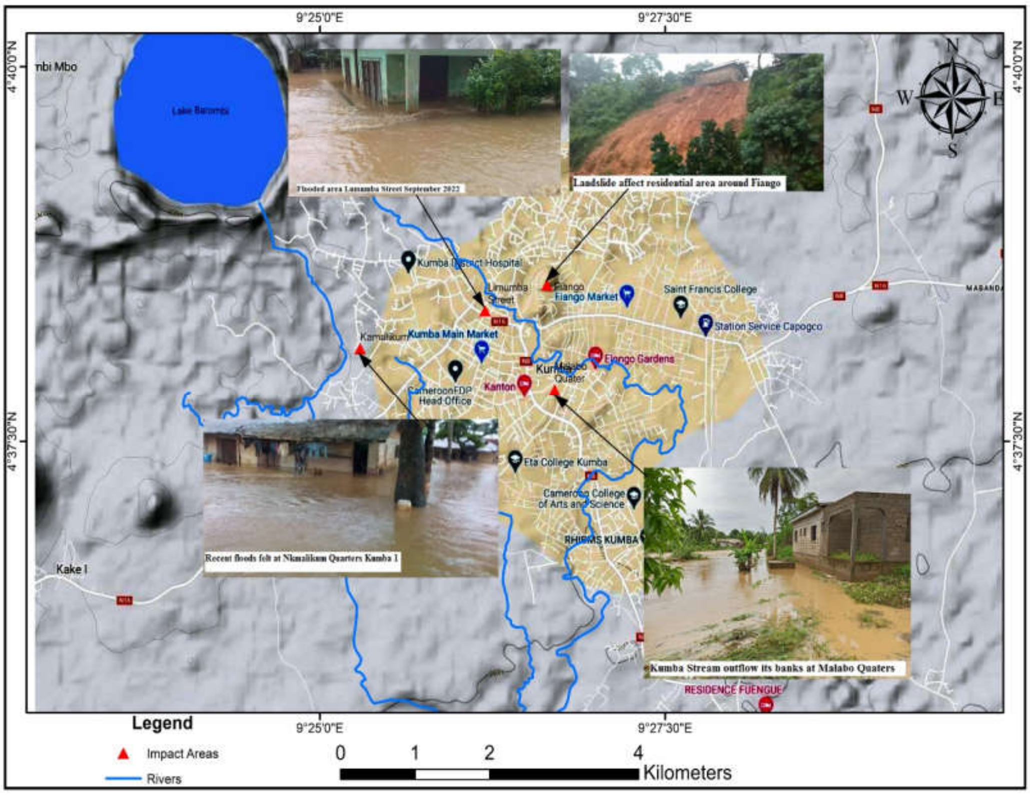


**b) Flood vulnerability areas of Mutengene and Likomba**

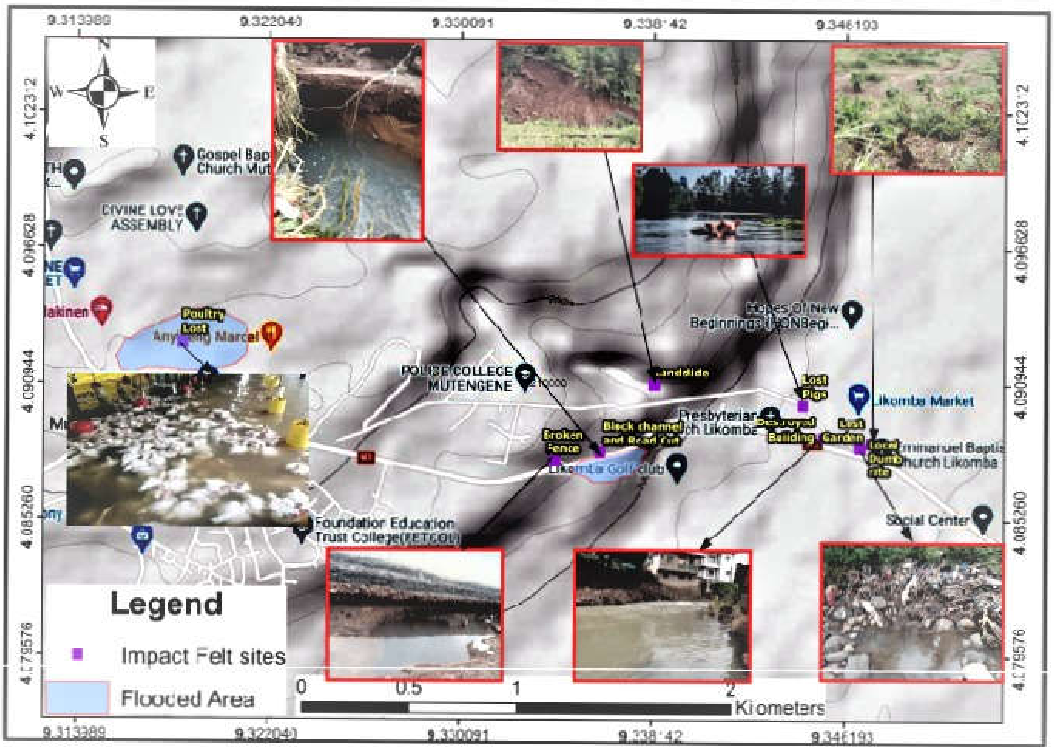
**Figure 2: Flood vulnerability maps of the area**

**Source: Designed from field data**

Noteworthy is that most of these new flood-impacted areas lie relatively far from the flood plain of the "Kumba Stream" and its tributaries. Nonetheless, they are along other important watercourses that have been almost obliterated encroaching human habitation and other activities. Floods especially of the magnitude recorded on 4th September 2022 are very unusual in the Mutengene-Likomba Zone. Sporadic floods occur in the Likomba area since it is low-lying on largely on the flood plain of" Likomba water" but are very rare within Mutengene since it is a settlement on mountain slope. Notwithstanding in early July 2022, the town of Mutengene recorded huge floods in the Plakenin Street, the Lamba Quarter, New Layout Quarter, Limbe Road around the Gospel Baptist Church, and Quarter One (Big mouth Market) and Quarter Two; on the Tiko Road around the Foundation Education Trust College, and highly abrasive torrents around the Police College on the Likomba Hill. These lie on areas where the terrain creates nodality and also seasonal and ephemeral waterways. In Likomba, the areas were the Golf Course Quarter, the local dumpsite area around the Emmanuel Baptist Church, the Hopes of New Beginning, the Presbyterian Church Likomba and Ndongo Quarter. The maps reveal that the most vulnerable areas to flooding and associated hazards are the low-lying areas, nodal points the stepped topography, river flood plains, dry valleys for inundations and steep deforested slopes for mass movements as earth flows and landslides.



a) Flood impacts in Kumba



b) Flood impacts in the Mutengene-Likomba Area

Figure 3: Flood impact maps

*Source: Designed from field data*

***Impacts of the flood Events:*** The July to September floods provoked intense inundation as usual but with sporadic landsides as the new mark of the floods on the landscape. The consequences recorded are summarised on Figure 3, showing the general and specific spots where casualties were recorded during the flood hazard. More inundation scenarios in Kumba are illustrated by the following pictures.

A new important dimension of the impacts of the flood story was the massive landscape excavation and scarification that emerged. Some pronounced cases are illustrated on Figure 6. Despite the fact that just 2/5 of the landscape in Kumba is characterised by steep slopes, the landslide event has equally put the city on the media headlines recently. Spatial location of landslides remained unaltered as areas along the slopes of central hills (the Hill Top, Baptist Hill and the

**Figure 4. More flooding scenarios in Kumba on 3 September, 2022**
*Source: Field Work, September 2022*

The Mutengene– Likomba many areas of inundation are shown on the following pictures.

**a) Human habitation invaded and drowned by flood waters on 9 July 2022 in Mutengene**

**b) Unprecedentedflood torrents gushing down the Main Road of Likomba Hill on 9 July, 2022**
**Figure 5: Inundations in the Mutengene- Likomba area on 9 July, 2022**
*Source: Fieldwork July, 2022*

Kumba II Council Hill zone) that occupy the north central part of the city, remained the endemic points of landslides in Kumba. Therefore, inhabiting hill slopes in Kumba has become tradition as such areas for long have not posed any real danger to occupying facilities. However, recent events that have associated floods and landslides have put such areas into perspective. The growing intensity, frequency and severity has caught attention and was the conspicuous dimension of these flood episodes. Although the Mutengene to Likomba zone is on a mountain slope, landslides are not frequent. The landslips and scouring of gullies on the sidewalks of the main road by the Police College and the Golf Course areas were new landscape mutations issuing from the 9July 2022 flooding scenarios.In addition to these symbols of landscape degradation and spoliation, incalculable number of human properties were destroyed in the drowned homes and many livelihood bases and infrastructure bastardised by the flood waters. within the Mutengene locality at the Lamba Quarter, a poultry was inundated and eight hundred (800) of the fowls drowned. This is shown on Figure 7.

**a) Landslides scars and roadside excavations around Police College Mutengene on 9 July, 2022**
**Figure 6: Landslides scenarios after the flood incidences**
***Source: Fieldwork (2022)***

**Figure 7. Fowls killed by inundation of a poultry house in Mutengene**
**Source: Fieldwork(2022)**

Also, many bags of animal feed bought and stockpiled were sucked beyond usage. Furthermore, the landslides and the flooding that covered the main road at hilltop area in Kumba and the Likomba Hill interrupted circulation for hours. Some vehicles notably taxis that forced their way through the flash floods suffered irreparable damages at their base with about 10 taxis having their engines knocked. Additionally, the 9 July and 4 September floods had another destructive dimension in common. Telecommunication lines of CAMTEL were unearthed and some severed as surface runoff dissected the landscape, engraving artificial channels. These are shown on Figure 8.

**Figure 8. Artificial channels on main road and banana plantations, and eroded reclaimed land at Likomba Area**
***Source: Fieldwork (2022)***

The case of Fiango is more pellucid as the Kumba IISubdivisional Council premises as well as the Cameroon Water Utility Company and Camtel installations have developed on these landslides affected hill slopes. The facilities of the Cameroon Baptist Convention equally found sited on the next hill slope opposite to those of the Council and Camtel installationsof underground cable lines and were also affected by the mass movements. The picture reveals dramatic consequences on the main road besides the Mutengene Police School. At some point along this road, overland flow from two different quarters convergedand the reinforced erosive force incised unwanteddrainage channels on the roadside with some of the gullies measuring 18 m long, 1.2 m wide and 2 m deep, indicating excavation of432 cubic metres of top soil lost at one point only. An intense landslide also occurred along the banks of River Likomba adjacent the main road in Likomba locality and the flash floods completely eroding to bare rock an 11.2 m stretch of some poorly reclaimed land on the narrow river flood plain. The flood waters washed away many makeshift structures that colonised the reclaimed land as stores, warehouses, snack bars, barbing saloons and a reserved spot for car washing activities.In addition, farmlands closer to the main road were actually affected as runoff diverted and inundating them and carving gullies in some parts. A modest estimated economic value of the damage caused by the floods of July to September 2022 in these two cosmopolitan areas lies in hundreds of millions. The scouring and erosion of river banks, debris deposition as well as the collapse of river banks could have been considered as the normal aftermaths of flood phenomenon precisely in the Mutengene-Likomba Community. However, what made the difference was the fledgling and the imperceptible dimension of environmental destruction as well as the human losses registered within a single flood event. For instance, the dredging of the CAMTEL underground communication systems and the creation of artificial channels of the dimensions measured along the Mutengene main road and the Kumba Hill Top landslide that missed by skin of the teeth burying a woman alive, coupled with the collateral sweeping off of houses and biodiversity, raised many unanswered questions in the affected communities as to whether the 2022 flooding were a natural cataclysmic phenomenon or a metaphysically driven disaster?

***The Flood Trigger mechanisms:*** The history of flood events research is fraught with the electrifying debate as to whether the root triggers are natural or anthropogenic. A deeper X-ray of both the natural and anthropic settings was done to establish the visible immediate triggers and latent less obvious drivers.

**Climate and weather condition:** This examined just the long term and the immediate flood period rainfall characteristics of the area since rainfall is the climatic parameter that directly induces flood events.

**Secular rainfall variability:** The Kumba and Mutengene- Likomba areasare located in the equatorial natural region. This place them within the *Af* tropical climate domain, according to the Koppen-Geiger classification characterised by high rainfall with a general mean rainfall of 2,000 mm. The mean annual rainfall (2015 to 2022) for Kumba (3,117.7 mm) and Mutengene-Likomba (2,351.7 mm) reveals that study areas are high moisture budget flux zones above their regional mean (2,000 mm). Annual trends of rainfall totals shown in Figure9, reveal overall decline over time.

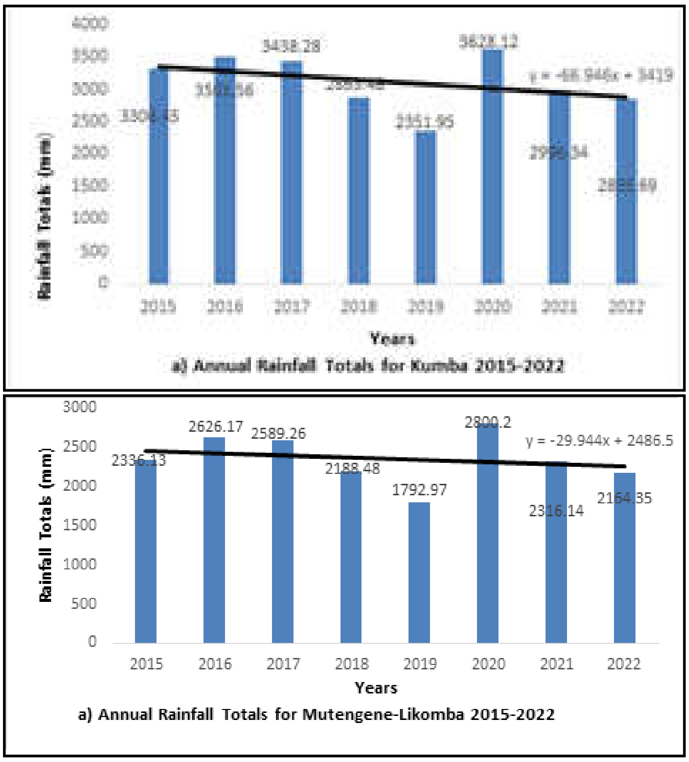


**Figure 9. Secular rainfall variability**
**Source: Drawn on the basis NASA Climatic Data**

Furthermore, the flood year 2022 was a drier year since the annual rainfall totals received (2,855.69 mm for Kumba) and (2164.35 mm for Mutengene-Likomba) were merely 91.6% and 92% respectively, of the established mean from 2015. Thus, rainfall in the year 2022 was generally about 8% lower than expected in these areas. Going by the empirical rainfall-flood nexus, the established declining annual rainfall trends and the relatively dry 2022 year, signify that flooding incidences should be less frequent and flooding scenarios less intense in these areas. Since the contrary picture prevails, it therefore means that inter annual rainfall patterns alone cannot adequately explain why floods events are becoming recurrent in Kumba during the last few years and particularly during the months of August and September and the extraordinary July 2022 floods in the Mutengene-Likomba Zone. Focus therefore must shift to the analysis of other rainfall indices for greater insights to this flood story.

***Seasonal Variability:*** The intra-annual analysis of mean rainfall totals from 2015 to 2022 reveals marked monthly differential in rainfall amounts as shown on Figures 10.

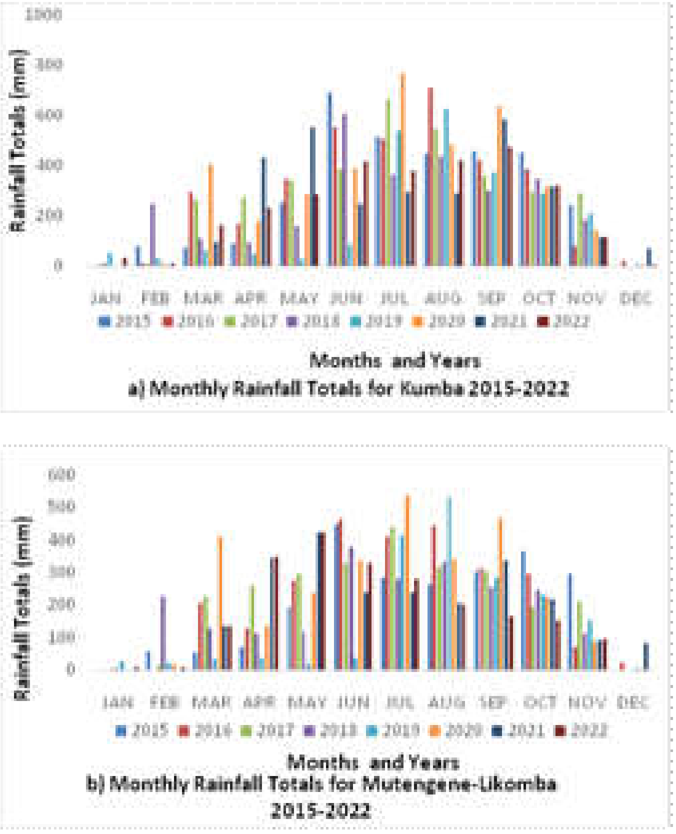


**Figure 10. Monthly rainfall totals**
**Source: Drawn on the basis NASA Climatic Data**

These indicate great seasonality in rainfall occurrence as in most tropical areas with excess concentration in the rainy season months (March to November in Kumba area and March to October in Mutengene-Likomba zone). The evolution of rainfall totals for the rainy season months between 2015 and 2022 shown on Figure 11, reveals that the proportion has been on the rising trend.

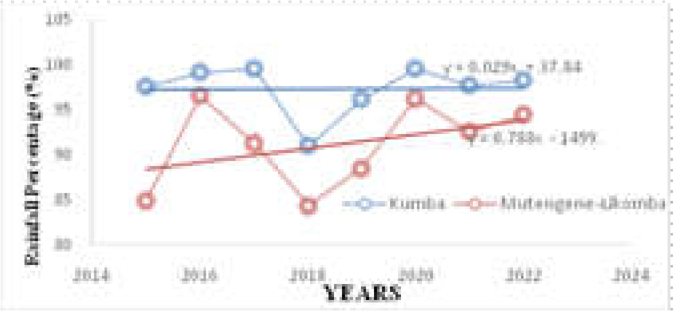


**Figure 11. Variation of proportion of rainy season rainfall totals**
**Source: Drawn on the basis NASA Climatic Data**

Analysis of the seasonal distribution rainfall in the flood year (2022) exposes critical rainfall-flood linkage facts. The rainy season months in the Kumba area received2,805.27 mm (98.23%) of the annual rainfall and the Mutengene-Likomba Zone, 2,044.15 mm (94.45%). These proportions were higher than the mean inter-annual rainy season rainfall proportions of 97.35% and 91.1% respectively.The monthly rainfall frequency (Figure 12) corroborates further this inter-monthly variation in rainfall.

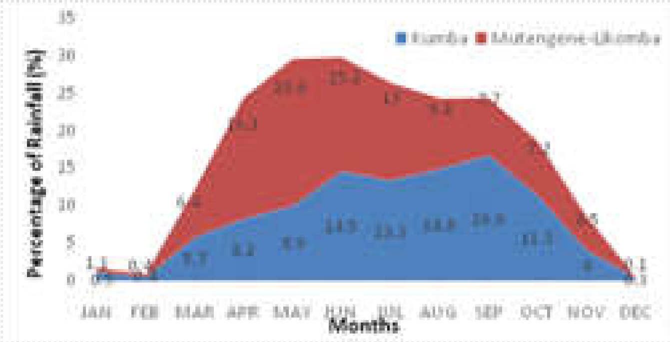
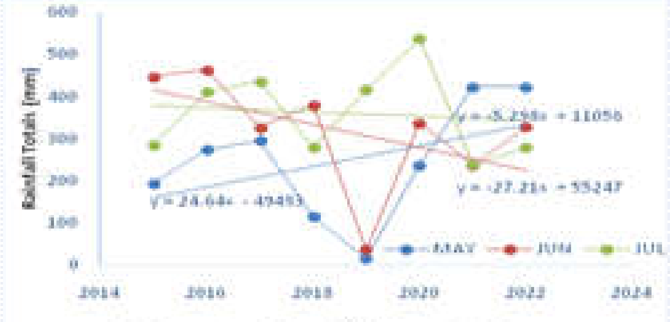


**Figure 12. Monthly Rainfall Frequency**
**Source: Drawn on the basis NASA Climatic Data**

An even distribution of rainfall across the year would have given a rainfall frequency or concentration ratio 8.3% a month, but unevenness was the occurrence. High rainfall concentration ratios (above 10%) occur in the months of April, May, June and July (63.9 % in just four months) in the Mutengene-Likomba zone and June, July, August, September and October (70.5% in five months). It is deciphered from this that the flood months (July in Mutengene-Likomba and September for Kumba) are high rainfall concentration months, with that of Kumba being the month with the highest rainfall concentration. This correlation between rainfall frequency and flood occurrence within these two areas therefore becomes clearer than merely looking at general seasonal distribution. Another dimension of analysis is examining the pattern of rainfall of the two months preceding the flood month and the flood month. This is important because rainy months preceding flood months contribute significantly to surface and subsurface moisture budgets which induce the overland flow that generates flood waters. In the Kumba area these months were July, August and September and in the Mutengene-Likomba zone, May, June and July. The interannual variation of this index shown on Figure 13, reveals that but for the flood month of September in Kumba and May in the Mutengene-Likomba zone where there is an increasing trend, the other months show declining trends.

a) Variation of Flood-months rainfall in Kumba (2015 to 2022)



b) Variation of flood-months rainfall in Mutengene-Likomba (2015 to 2022)

**Figure 13. Inter-annual Variation of Rainfall for pre-flood months**
**Source: Drawn on the basis NASA Climatic Data**

Since the floods occurred within the first ten days in the flood months, it means the amount of rainfall that watered the lands in the two months preceding the floods months become very critical. In the year 2022, thepre-flood months rainfall totals in the Mutengene-Likomba zone ( May and June) are higher than the means totals between 2015 and 2022 but in the flood months (July) it is lower (Figure 14).

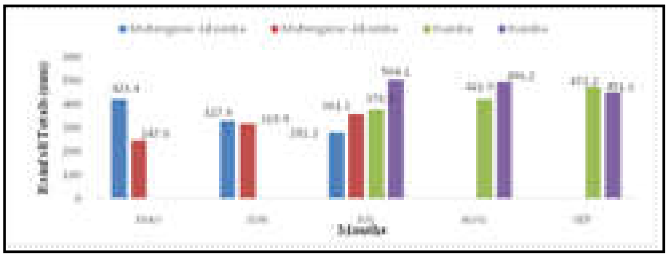
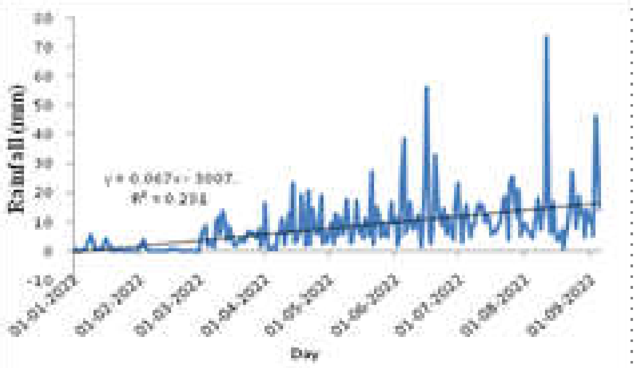


**Figure 14. Rainfall totals for pre-flood months**
**Source: Drawn on the basis NASA Climatic Data**

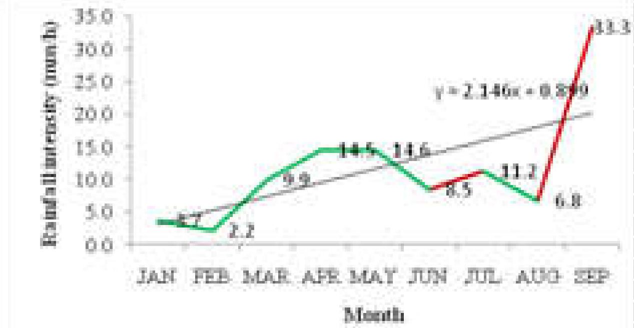
In the Kumba area, rainfall totals in the pre-flood months (July and August) are lower than the inter-annual mean, but for the flood month (September) it is higher. These facts reveal that in the Mutengene-Likomba zone, the intense rainfall in the months before the floods of 9 July 2022 saturated the soil more than usual and so generated much overland flow that led to the flood waters. In the kumba area, although the pre-flood month rainfall totals were high, they were less than the mean total rainfall. so the contribution to floods was less likely than in past years. Since the September floods occurred very early in the month (4th September)rainfall totals of the month of septemebr though higher than the inter-annual mean cannot cannot provide a valid and reliable explanation for the floods. However, sincethe flood months follow the peak rainfall months, the floods are linked to fact that from July to September, antecedent soil moisture is high to saturation levels and the soils are saturated and impermeable to infiltration thereby favouring higher volumes of overland flow. The huge volumes of surface run off spread over the land and fills low-lying areas, thereby generating the flooding scenarios.

**Mean Rainfall Intensities:** The amount of rainfall occurring within unit time is crucial in rainfall-flood analysis since it determines the infiltration rate and capacity of an area hence the rainfall-run off coefficient. The daily rainfall variability and mean rainfall intensities of the areas on Figure 15, reveal upsurges in the flood months of September in Kumba and July in the Mutengene-Likomba zone.

Figures 15 a and b reveal that daily rainfall totals and rainfall intensity increased towards the flood occurrence months. september in both areas. The sudden rise in the flood months was the immediate trigger of the July-September floods. The July 9th 2022 flood hazard in the Mutengene-Likomba zone was the result of two days continuous intense rainfall, and the 4 September floods connected to more than four days of similar rainfall characteristics. These rainfall charcteristics brought in abundant input of water to surface, that reduced the infiltration rate consequently generating the great volumes of high velocity overland flow which provoked and sustained the floods that overwhelmed the surface drainage capacity. Furthermore, the torrents of overland flow into streams amd dry valleys generated higher flood waters well above the carrying capacities of the channels.The great volume and velocity of the overland flow, catalysed its erosive potential hence the ecavation of gullies and unearthing of infrastructure (Figures 6 and 8). The rainfall characteristics in the pre-flood months but more especially the extreme rain events in the pre-flood occurrence days provide ample explanation of the unprecedented floods. However, the magnitude of the flood incidence necessitate recourse to be made to under indirect flood drivers. The rainfall characteristics in the pre-flood months but more especially the extreme rain events in the pre-flood occurrence days provide ample explanation of the unprecedented floods. However, the magnitude of the flood incidence necessitate recourse to be made to under indirect flood drivers.



a) Daily Rainfall variability for Kumba in 2022



b) Mean monthly rainfall intensity for Mutengene-Likomba

c) Mean Monthly Rainfall Intensity for Kumba

**Figure 15. Monthly Rainfall Intensities**
**Source: Drawn on the basis NASA Climatic Data**

**The indirect flood drivers:** Nature of activities as well as the environment have a lot of influence on the extent of flood occurrences in any locality. Consequently, this study examined the traits of the natural and an thropic environment that induce flooding from rainfall.

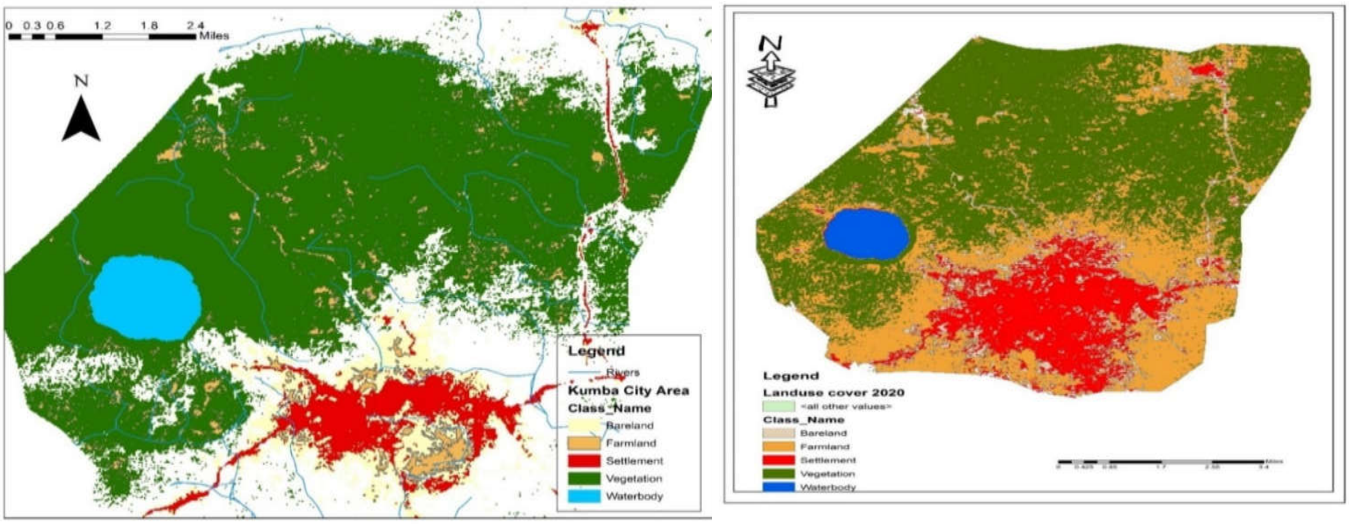
**Terrestrial geography:** This streamlined the natural landscape patterns with flood enabling dimensions. Field observations revealed that the topography of Kumba is undulating with tablelands, hillocks dissected by rivers with adjoining narrow flood plains.The Mutengene – Likomba zone is a complex landscape of convexand concave slopes with nodal terraces and depressions, crisscrossed by few predominantly dry valleys, tilting steeply towards the Likomba plains.The slopy topography of the flooded areas induced the floods as they reduced the infiltration capacity of the landscape by accelerating the overland flow thereby generating great volumes of high-speed surface runoff that spread over the land. During the flood events, huge volumes of run off rushed down the slopes and through the hitherto dry valleys. Also, the terraces, depressions and low-lying areas slowed the speed of overland flow thereby forcing the water to spread and inundate surrounding areas creating ephemeral lakes on the surface. Houses in such locations were drowned by the rising flood waters (Figures5).This analysis reveals that though the rainfall generated much surface runoff, the terrestrial geography contributed significantly in triggering the floods, landslides and soil slumps of early, July and September, 2022.

**Landscape humanization:** Though the rainfall flood nexus has been established,the unprecedented pattern of occurrence of the July 9 -September 4, 2022 flood warrantssearch for explanations beyond the nature-driven floods thesis.Consequently, an evaluation was made of the likely enabling connections of the floods and the vast landscape humanisation stemming from anthropic obstructions, constructions and destructions. Infrastructural designs and patterns have actually been done in respect to the topography of the area. Here, most of the housing facilities are made with planks “caraboots” while there are few in block and stone materials. Most of the houses clustered on the favourable locations for constructionas the tablelands, hilltops, gentle slopes, plains and terraces. This clustering has installed a high housing density which is deepening and widening with time, with house spacing in most low-lying parts being 1 to 2m apart and also less than 2m away from the main road. This high nucleation of houses increases friction to overland flow thereby increasing surface detention and retention of water within the narrow tracks between the houses. this situation is exacerbated the preponderance of housing constructions directly on the natural, as well as the man-made drainage channels. These constructions constituted growing instances of drainage channels obstructions in area. Some of these unplanned construction of houses along the Likomba Riverbanks are shown Figures 16 A and B while artificial blockage of drainagechannels is on Figure 16 C.

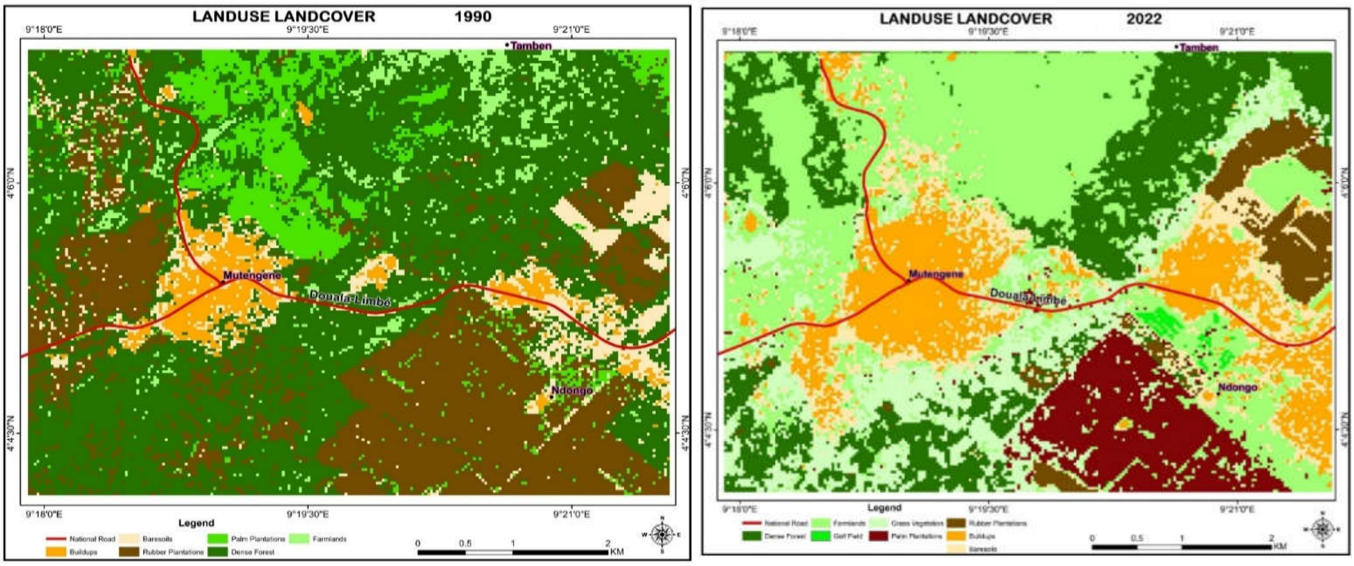
**Figures 16. Scenes of anthropic constructions and obstructions on water course ways**
**Source: Fieldwork, 2022**

The reducing impacts of these landscape distortions on the natural evacuation of overland flow was compounded further by the fact that man-made drainage channels were very evenly distributed within the areas and the few available very shallow compared to the natural ones. Gutters in this zone averagely measured just 70 cm wideand 70cm deep. Worse still, these gutters have been transformed by the inhabitants into solid and liquid waste dumps and farming activities have encroached into some.In some parts, the drainage channels end abruptly because of these constructions. The foundations of most houses start directly from the river bed and now form artificial river banks.Pronounced agricultural activities were noted on the moist and fertile alluvial soils on the exposed river beds, river banks and marshlands in the endemic flood zones. Few carried out subsistence and commercial mixed crop cultivation of maize, tubers and vegetables and even monocultural growing of banana, palms and rubber.Piggery and poultry farming are also done by a majority of the population.Small business activities have developed in these areas with shops, stores, beer parlours and other related economic opened by individuals on these river plains and dry beds. These human activities entail removal of vegetation, land reclamation, filling up of natural channels as well as diverting the natural water runways.The permeability of soils was reduced by lose soil particles that increased sedimentation rateand the concreting from constructions. These have blockedmany of the channels, making them narrow and shallow, thereby reducing the volumetric water carrying capacity to discharge run off. Furthermore, these human intrusions increased the roughness of the channel and therefore more friction on channel runoff. With most natural channels already illegally reclaimed for house constructions and other economic activities, the heavy downpours of the weeks of 9 July and 4 September, 2022, gushed into these reduced-capacity drains. As the water carrying capacity of these drains was surpassed, diversion of overland flow from these channels onto the landscape resulted, thereby inducing the flooding scenarioshaphazardly into nearby homes. An unfortunate observation was the likelihood of little attention on the nature of the drainage system by the authorities and locals, since many obstacles within the drainage channels had been there for a long period of time. The overall consequence of this extensive domestication of the landscapes has been the significant land use land cover (LULC) mutations which have increased the susceptibility of the areas to flooding and linked effects. These changes are between 1990 and 2022 are shown on Figures 17.

The temporal mutations of land cover (forest and water bodies) and land use (farmland and settlement) aspects intricately linked to hydrological flows as run off and infiltration expressed on the maps are summarised on Table1. The figures reveal significant land cover land use mutations in all parts of the study area. in favour of rapid expansion of major and use as. In the Kumba area by 2022, cumulatively forest cover and water bodies reduced by 45.4% while in the Mutengene-Likomba Zone the decline was eve higher (64%). On the other hand, built-up areas and farmlands expanded exponentially by 167.6% and Mutengene-Likomba Zone by 67.8%. These landscape modifications induced significant flood implications. Forest cover reduction has made the surfaces bare and has thereby nullified the modifying effects of vegetation on high intensity rainfall. The extensive built-up areas have reduced the permeability of the surface thereby reducing the infiltration rate and capacity of the area.



**a) LULC 1980 and 2020for Kumba from Mokom J. (2021)**



**b) LULC 1996 and 2022 for Mutengene and Likomba Zone by Nkendem (2022)**
**Figure 17: Land Use and Land Cover evolution in the areas**
**Source: Designed from satelliteimages**

**Table 1. Land useland cover changes**

| Landscape Aspects | Kumba | | | | Mutengene - Likomba | | | |
|---|---|---|---|---|---|---|---|---|
| | 1980 ($km^2$) | 2020 ($km^2$) | Nature of Change | | 1996 (ha) | 2022 (ha) | Nature of Change | |
| | | | $km^2$ | % | | | (ha) | % |
| Land cover | 97 | 53 | 44 | 45.4 | 1, 676 | 604 | 1072 | 64 |
| Land uses | 34 | 91 | 57 | 167.6 | 1, 411 | 2,367 | 956 | 67.8 |

Source: Analysis of Land Use-Land Cover Maps

The coincidence of the very high rainfall intensity of the flood-period with the reduced permeability of the surfaces increased the volume of overland flow. These great volumes of water flowing through drains and urban streams with reduced water transmission capacities, provoked over flow of water unto the surface. The unprecedented July-September 2022 floods stemmed from the modificationsin the land cover-land use and rainfall nexus in relation to generation of flood waters. A significant consequence of the flood season was the occurrence of landslides in both areas which were linked to the same mutations in the process-response relationship between the landscape and climate.Slope material maintains a delicate equilibrium with the vegetation and rainfall, which any significant changes in the Land Cover-Land Use destabilises slope stability. The continuous rainfall of the 2022 July-September months on largely deforested slopes,oversaturated the slope materials, increased its weight and the shear stress and lubricated the cleavage layer (Genene and Thokozani 2016). The forceof gravity combined with the growing weight of rising constructions precipitated large masses of supersaturated soil, stones and other debristo slump down slope. Furthermore, the high rainfall intensities generated great torrents with high erosive power that provoked mudflows and scoured incised gullies and small ravines in some areas. The increasing frequency and magnitude of mass movements recorded in the steeper areas of these zones were jointly explained by changing land cover-land use and rainfall characteristics.

# DISCUSSIONS

The July 9 and September 4, 2022 floods have been attested as one of the most devastating floods recorded in these localities. Farmlands (fertile soils and crops) and domestic animals precisely poultries and piggeries were destroyed. These results were in line with those of Ghapar*et al.,* (2018) who underscored that most incidences of environmental degradation such as soil erosion and the linked farmland destruction and biodiversity loss are often the outcomes of devastating flood incidences.Houses as well as housing materials were affected leaving many homeless within that period as runoff inundated and occupied most households. Also, many children within the affected areas suffered from of waterborne diseases such as diarrhoea, dysentery, as well as malaria from mosquitoes. Aqueducts and water distribution pipes were broken thereby disrupting the general water supply systems and polluting the water. These findings were consistent with that of OCHA (2015) that the intense rainfall that occurred in 2014 in Southern Africa displaced thousands of residents and household occupants temporarily migrated to nearby countries.These observations also confirmed the findings of Oppong (2011) writing on challenges of flood occurrence in the city of Accra in Ghana noted that most of the victims became homeless, their property damaged as well as the emergence of health issues.

The relatively higher rainfall frequency, proportion and intensities in the 2022 flood months compared to previous years coupled with the modification of the landscape, were critical triggers of the unprecedented floods and the associated consequences. This observation was corroborated by Baldassare *et al.,* (2010) who noted that the cause of the September 2009 floods in West Africa, precisely in Senegal and Burkina Faso, that affected 600,000 people was to a greater extent triggered by torrential rain within the months of July and August. These results are also in line with those of Km Vandana *et al.,* (2014) who noted that the cause of flood on hilly areas of Uttrakhand and Himachal was mostly due to snow melting and the outburst of cloud. Rapid urbanisation has been blamed on the increase in hazard occurrences in urban areas across the coastal cities in Cameroon (Balgah *et al.,* 2018). In Kumba area, urban poverty leads to the colonisation of risk prone areas within the city (Fombe *et al.,* 2014; and Kimengsi *et al.*, 2016).Household as well as commercial waste materials are often disposed in nearby streams, rivers as well as into the nearby drainage channels. Major livelihoods activities as farming and petty businesses were found commonly practised on stream banks and poorly reclaimed flood plains, thereby narrowing the streams' capacity to drain flood waters. These factstied with the human improper colonisation of flood drains linked to rapid urbanisation long analysed (Ndille*et al.*, 2013, Fombe *et al.,* 2014 & Kimengsi *et al.,* 2015Fogwe &Ngum 2016, Balgah & Nkemasong 2018) as key in endemic floods in Kumba. Furthermore, housing structures and patterns are poorly design with most of the structures being constructed within drainage channels and close to the main road with limited spacing between these structures. These usually prevent the outward movement of water generated within the different quarters and thus, often resulted into severe floods. These results confirmed those of Musa *et al.,* (2014) who in assessing flood challenges in Gusoro noted that reckless human activities and poor structuring of houses were the major causes of flood in the area.

# CONCLUSION

The analysis of climate variability and hazard occurrence in the Kumba Municipality was aimed at establishing the relationship between the recurrent floods and landslides with climatic data. It reveals that there is a great relationship between floods and landslide events and the prevailing climatic characteristics in the study area. The analysis has equally revealed that much literature exist on the issues of floods in Kumba (DDEPD 2013, Fogwe & Ngum 2016, Balgah & Nkemasong 2018), with plausible recommendations. However, the fact that floods have remained endemic, despites the many recommendations towards mitigating them in the study area has become more preoccupying. It becomes even more aching owing to the fact that while floods continue to create havoc in the low-lying parts of the city, landslides are making upper slopes inhabitable. Unlike floods in the Kumba Area, landslides events in both areas have not received unequivocal attention, yet their effects are gaining strength on both the human and environmental dimensions. Landslides are important hydro-climatic hazards whose occurrence will surge with the recent anthropogenic climate change (Banlilon&Suiven 2019, Genene & Thokozani, 2016). It is therefore, important that landslide prone areas within the city of Kumba be mapped out as the case with floods zones developed by the City Council Authorities. Accordingly, it has become very imperative for the City Authorities to develop capacity towards addressing landslide and floods issues within the city of Kumba. This requires the creation of a research unit, technical service and above all undertakes sensitisation campaigns towards the population. This call is more urgent in the Tiko Municipality within which the Mutengene-Likomba zone falls because none of these hazards has caught public attention as in Kumba. if adequate and participatory measures are not put in place to mitigate the challenges of these hazards, most sustenance activities practised by the population shall be greatly destroyed thus, rendering bleak the future of the inhabitants the area.

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## APPENDICES

### Monthly Rainfall Totals from 2015 to 2022 Kumba

**Kumba Area**

| Years/Months | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 0 | 79.1 | 73.83 | 89.65 | 253.12 | 690.82 | 516.8 | 448.24 | 458.79 | 453.52 | 242.58 | 0 |
| 2016 | 0 | 10.55 | 295.31 | 168.75 | 348.05 | 553.71 | 506.25 | 711.91 | 421.88 | 384.96 | 79.1 | 21.09 |
| 2017 | 5.27 | 10.55 | 263.67 | 274.22 | 342.77 | 384.96 | 664.45 | 548.44 | 358.59 | 295.31 | 290.04 | 0 |
| 2018 | 10.55 | 247.85 | 110.74 | 94.92 | 158.2 | 606.45 | 363.87 | 437.7 | 300.59 | 348.05 | 184.57 | 0 |
| 2019 | 52.73 | 31.64 | 63.28 | 47.46 | 26.37 | 84.38 | 537.89 | 627.54 | 374.41 | 290.04 | 210.94 | 5.27 |
| 2020 | 0 | 10.55 | 406.05 | 179.3 | 284.77 | 390.23 | 769.92 | 485.16 | 638.09 | 316.41 | 142.38 | 5.27 |
| 2021 | 0 | 0 | 94.92 | 430.52 | 555.23 | 249.61 | 294.43 | 288.57 | 583.09 | 315.38 | 114.39 | 70.2 |
| 2022 | 31 | 12.12 | 162.62 | 232.96 | 284.09 | 415.25 | 378.94 | 421.87 | 473.23 | 323.1 | 113.21 | 7.3 |

**Mutengene-Likomba Area**

| Years/Months | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 0 | 58.01 | 52.73 | 68.55 | 195.12 | 448.24 | 284.77 | 263.67 | 305.86 | 363.87 | 295.31 | 0 |
| 2016 | 0 | 0 | 205.66 | 126.56 | 274.22 | 464.06 | 411.33 | 442.97 | 316.41 | 295.31 | 68.55 | 21.09 |
| 2017 | 5.27 | 10.55 | 226.76 | 258.4 | 295.31 | 326.95 | 437.7 | 316.41 | 305.86 | 195.12 | 210.94 | 0 |
| 2018 | 5.27 | 226.76 | 126.56 | 110.74 | 116.02 | 379.69 | 279.49 | 332.23 | 253.12 | 247.85 | 110.74 | 0 |
| 2019 | 26.37 | 21.09 | 31.64 | 36.91 | 15.82 | 36.91 | 416.6 | 532.62 | 284.77 | 232.03 | 152.93 | 5.27 |
| 2020 | 0 | 15.82 | 411.33 | 137.11 | 237.3 | 337.5 | 537.89 | 342.77 | 469.34 | 221.48 | 84.38 | 5.27 |
| 2021 | 0 | 0 | 137.11 | 347.03 | 423.51 | 237.55 | 239.85 | 205.18 | 337.64 | 216.72 | 89.04 | 82.5 |
| 2022 | 11.1 | 8.8 | 138.81 | 348.28 | 423.37 | 327.94 | 281.15 | 203.01 | 166.39 | 155.2 | 98.2 | 2.1 |

### Number of Rainfall days in 2022

| Place/Months | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Kumba | 9 | 4 | 25 | 27 | 28 | 30 | 29 | 29 | 5 | 186 |
| Mutengene - Likomba | 3 | 4 | 14 | 24 | 29 | 28 | 25 | 30 | 5 | 162 |

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