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Rainfall Variability, Flood Hazards and Adaptation Strategies in Douala IV and V Municipalities, Littoral Region of Cameroon

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Abstract

Excessive rainfall resulting to floods remain a thorny problem in developing countries including Cameroon. This follows the negative impacts of floods on the population, infrastructure and public services. This study examines rainfall variability, population vulnerability to floods and measures put in place by the population and other stakeholders to adapt to the situation in the Douala IV and V municipalities in Littoral Cameroon. The study exploits both primary and secondary sources data for its realization. Heads of households, quarter's heads, municipal authorities and its personnel, and public administrative officials were contacted for data collection. The data focused on floods manifestation, their effects on the city, and adaptation strategies put in place to mitigate the negative outcomes. Data from semi structured interview conducted were analyzed using content analysis methods. Sociological and spatial data also collected were analyzed using remotely sensed techniques and statistical tools such as SPSS and Microsoft excel. Climatic data were collected from the urban council, the meteorological units in the town and the National Observatory on Climate Change of Cameroon. Sequential analyses (linear trend curves, standard deviations, and cumulative balances) were used to evaluate the evolution of rainfall and correlation to floods events. The result revealed that floods in Douala IV and V result from rainfall variability, characterized by deficit and excessive rains in the months of June, July, August and September. These heavy rains accompanied by human induced factors such as uncontrolled urbanization, anarchy in construction and occupation of wetlands, poor waste management, pollution of water ways and lack of drains for stagnant water evacuation leads to floods. Also, natural drivers such as the low relief of the area, a dense hydrographic network and contact with the Atlantic Ocean via the Wouri estuary result to floods. These floods are a problem to the health of the population, public services and infrastructure and sustainability of the city. Faced with the numerous damages caused by floods, remediation strategies such as: the construction of traditional dikes, solid house foundations, water embankments, and periodic weather forecasting by the National Observatory on Climate Change of Cameroon to reduce the negative outcomes of flooding has been ineffective in reduction of floods outcomes. Consequently, floods still remains a concern in Douala town. Good environmental practices such as civil education on hygiene and sanitation, periodic cleaning of drains, combats on deforestation of mangroves and afforestation campaigns, government investment on decentralization of waste collection and management will be productive in reducing the effects of floods in Douala. The implementation of all these remedial measures will not only ensure the safety of vulnerable civilian populations but the protection of their activities.

Keywords: Rainfall variability, vulnerability, floods, population, adaptation Strategy, Douala IV and V.

1. INTRODUCTION

Natural disasters and their effects on the population and environment have increased tremendously and are becoming an issue of preoccupation in the world today. According to the United Nation Strategy for Disaster Reduction (UISDR, 2002), the number of storms, floods, droughts, and landslides have increased threefold over the past 30 years due to global warming and climate change. There has been a widespread increase in heavy and extreme precipitation leading to flood events in many regions of the world (IPCC TAR, 2001a). Decrease in agricultural production, scarcity in fresh water, increase in infection diseases, degradation of local livelihoods and human well-being are some of the consequences of floods. In Cameroon, heavy rainfall at the end of July resulted to

river overflow in Cameroon's Far North (Extreme-Nord) region, affecting over 5,000 people and more flooding recording reports in the area, with over 1,500 families displaced in areas around Maroua.

Douala metropole within which Douala IV and V municipalities are found is socially and environmentally vulnerable to catastrophic flood events. The town has a tropical monsoon climate, with a yearly temperature of 28◦C, characterized by heavy precipitation especially during the rainy season from June to October. The geographical location of Douala IV and V in a coastal mangrove ecosystem makes the town vulnerable to periodic rise of sea levels and floods risk. In addition, Douala's low relief of 13m above sea level, favours the stagnation of water in the environment after rain episode. This coupled with its poor drainage systems favours river overflow. Anthropic factors such as deforestation characterized by the recurrent cutting down of trees that act as a natural buffer against floods, poor waste management, and absences of drains increases flood vulnerability.

This study focuses on the influences of rainfall on floods within the Douala IV and V municipalities, determinants of floods, effects and adaptation strategies of stakeholders on floods in the study sites.

2. The study area and methodology

2.1 The study area

Douala IV and V is located in the Wouri Division of the Littoral Region of Cameroon. These municipalities are currently controlled by the Douala Urban Council [CUD]. Douala is the largest city in Cameroon and it the economic capital hub of the country and the CEMAC zone in general. Douala town is located on the coast of the Gulf of Guinea and lies between Latitude 03° 40-04° 11' N of the equator and Longitude 09° 16'-09° 52'E of the Green Wish Meridian [figure 1]. Douala town has an elevation of 13m above sea level and a surface area of 210km^2. It is bordered to the North by the Mongo division [headquarter Nkongsamba], North East by Nkam division [Yabassi], to the East by Sanaga Maritime, South by Douala VI, I, II and III and to the West by the Fako Division in the Southwest of Cameroon. It is drained by the Wouri River and it tributaries. Figure 1 shows the location map of Douala IV and V in the Wouri Division.

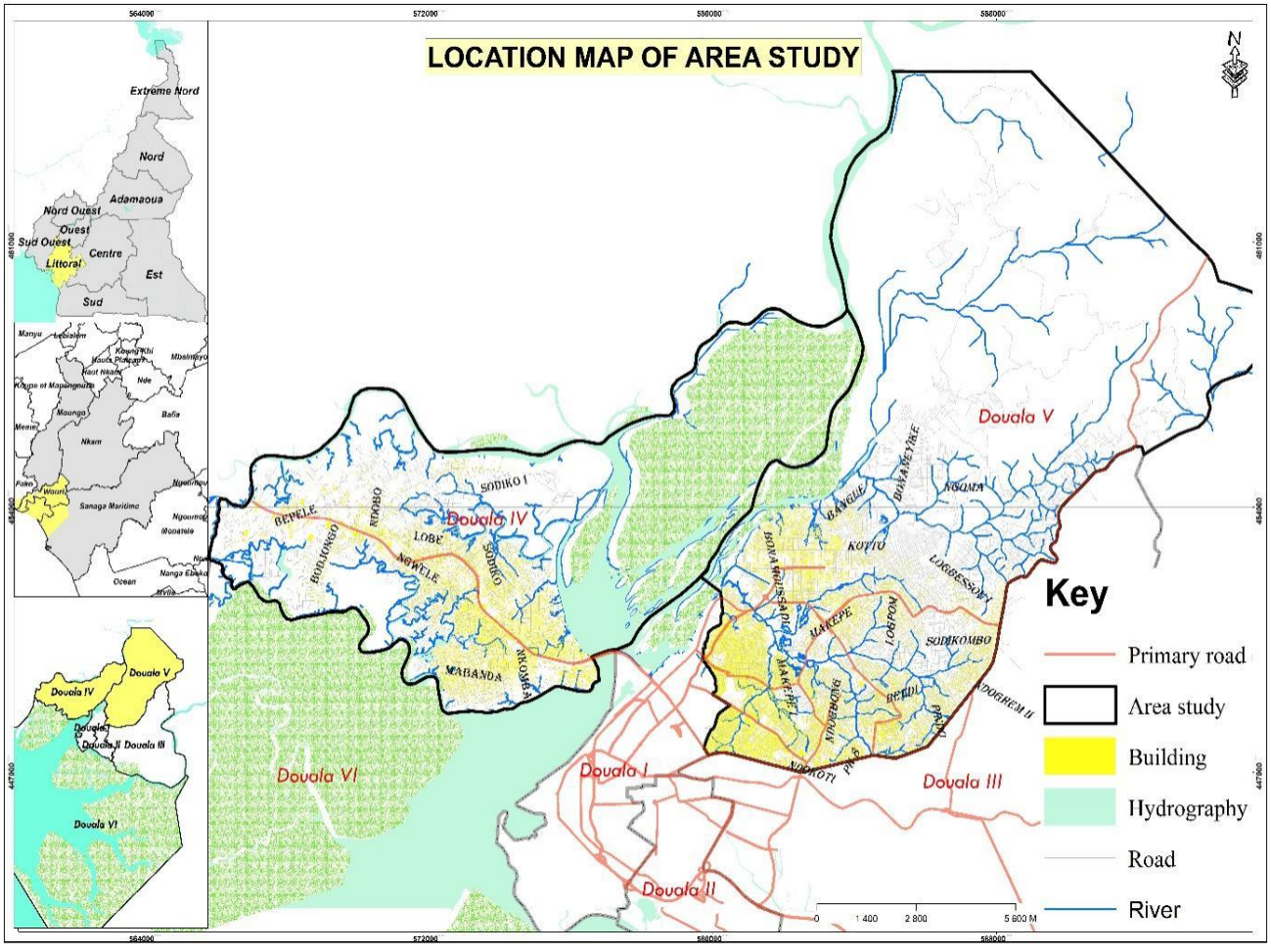

Figure 1: Location of Douala IV and V Municipalities

2.2 METHODOLOGY

The findings of this paper used qualitative and quantitative research designs as the methodological frameworks. Both primary and secondary sources material have been exploited for the findings. Part of data for this paper is an extract of a PhD thesis being carried out by the author in the town of Douala. Heads of households, quarter heads, municipal authorities and personnel, and representatives of public administrative service related to flood management were contacted for data collection. The data focus on floods manifestation, their effects on Douala, and various adaptation strategies put in place to mitigate the situation. 479 questionnaires were administered for sociological data collection in households of quarters that are vulnerable to flood within the Douala IV and V municipalities. These quarters are Mabanda, Grand Hanger, Washington, Logpom, Makepe, Missoke and Melangue. In addition, semi structured interviews were conducted for Information on flood impacts and adaptation strategies. The resource persons targeted were city mayors and councilors, heads of administrative services related to floods disaster management such as Civil Protection and Urban Planning personnels, quarter heads, and agents of the Meteorological Service. The Douala Meteorological Station and the National Observatory on Climate Change of Cameroon provided climatic data for analysis of rainfall and its effects on floods. Sociological data from semi structured interview were exploited by content analysis and geo spatial data treated using mapping and remote sensing software. Descriptive and inferential statistics have been managed using statistical tools such as SPSS and micro soft excel. Sequential analyses (linear trend curves, standard deviations, and cumulative balances) were used to present and interpret the evolution of rainfall and correlation to floods events. Inter-annual anomalies of rainfall have been computed using Microsoft Excel to assess variability of rainfall over the past 29 years (1992-2020). Bifurcation ratio have also been computed to identify the streams or drainage basin influences on flood occurrence. Photographs taken during direct field observations have been integrated in the paper to show the magnitude of floods and problems in the study site. The results of the study are shown in the section that follows.

3. RESULTS AND DISCUSSION

There are other natural factors [low-lying relief and dense hydrological network] and human induced factors [anarchy in urban construction and invasion of wetlands, poor waste management, and pollution of waterways and lack of drains for stagnant water evacuation] leads to floods. These floods are a problem to the health of the population, public services and infrastructure and sustainability of the city. Remediation strategies used to reduce the negative outcomes of flooding in Douala IV and V.

3.2 Determinants of floods

3.1.1. Rainfall variability 1992 – 2020

The study reveals that there has been a remarkable fluctuation in rainfall characterized by deficit and excessive rains in the months of June, July, August and September over the past years (1992-2020). This rainfall remains the primary factor of flood vulnerability. The significance of rainfall variability in Douala town, is seen on Figure 2.

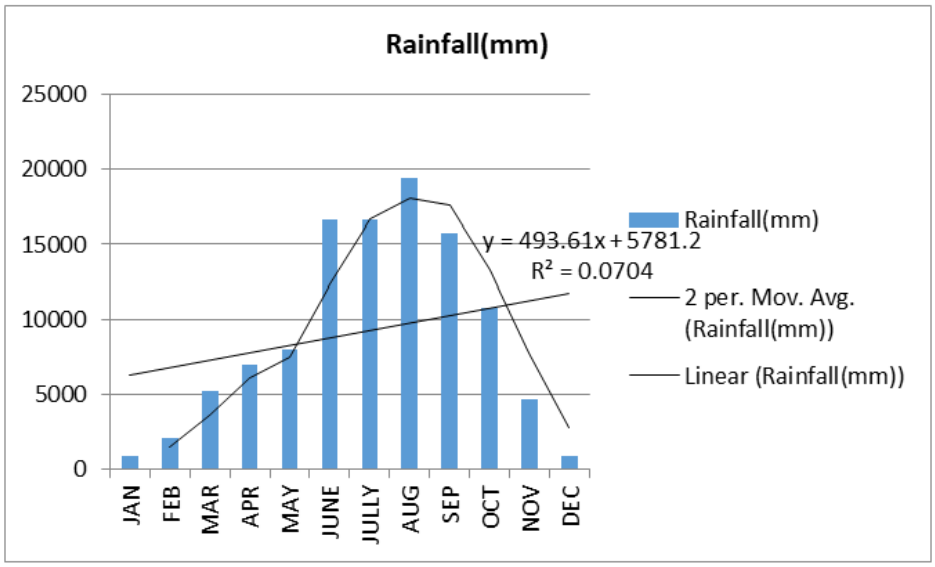

Figure 2: Total monthly rainfall 1992-2020

Source: Computed by authors from data of NOCC and Douala Meteorological Station

Figure 2 shows, total monthly rainfall was not stable over the period under study with some months receiving more rainfall than others. The highest rainfall was registered between June and October with August having the highest total rainfall (19459.2 mm). This high volume of rainfall is not a health condition for Douala

and its population as it increases their vulnerability to floods. The months of December and January have the lowest total rainfall with 855.15mm and 862.9mm respectively. These months experience the highest evapotranspiration due to longer hours of sunshine. They are the driest months, characterized by reduction in water levels and flood risk.

3.1.1 Observe Inter-annual Rainfall trends

The inter-annual total rainfall in Douala IV and V also varies. There has been a steady variation in total annual rainfall from 1992 to 2020. Some years had over 4000mm per year and others lower than 3000mm per year. The year 2000 and 2006 recorded the highest total annual rainfall with each having 7454.8mm and 4588.6mm respectively. This high total annual rainfall exposes the population of Douala to extreme hydro-meteorological events such as flood, landslide and in some cases storms. The rainfall data trend from 1992 to 2020 is presented on Figure 3.

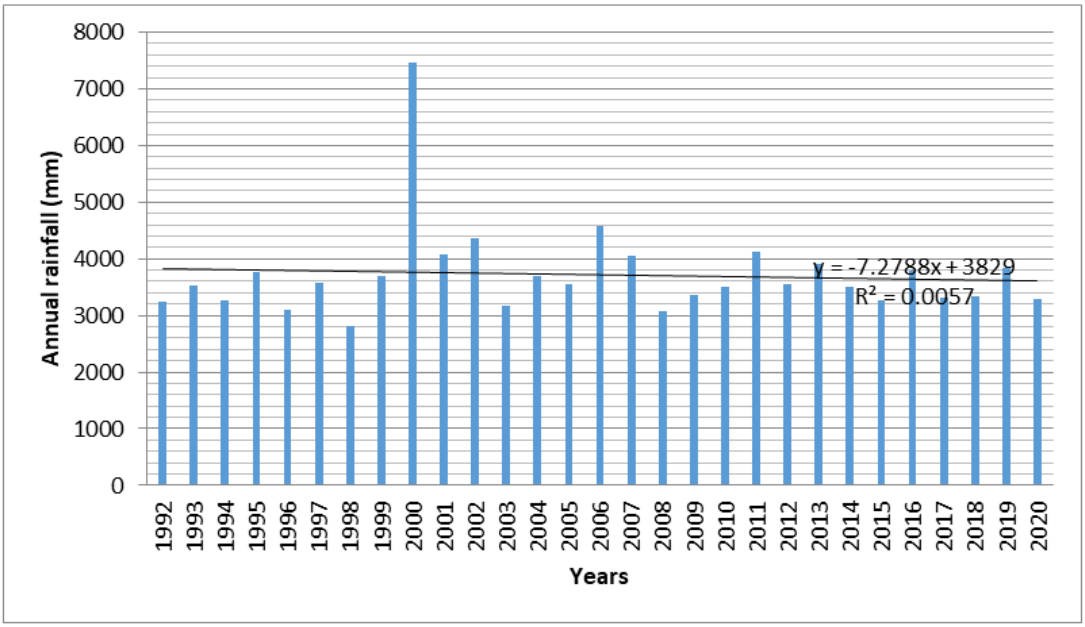

Figure 3: Inter-annual total rainfall variability in Douala from 1992-2020
Source: Researcher 2020, NOCC and Douala Meteorological Station

Figure 3 shows that fluctuations occurred in yearly rainfall. These years were 1996 [3106.4mm], 1998 [2813.9mm], 1992 [3245mm] and 2020 [3288.1mm]. A reduction in rainfall amount was witnessed during these years with risk of mild drought conditions experienced. These high rainfall in Douala is a factor that exposes the of Doauala IV and V population to floods risk. Apart from high rainfall other factors contribute to increase vulnerability of the population to floods.

3.1.2 Dense hydrological network

Douala IV and V has a dense hydrological network within its nine drainage basins. These basins are Tongo-Bassa, Bonangang, Nsape, Nkondibe, Korer, Basseke, watershed 1, 2 and 3 (figure 4). The town is mostly drained by the Wouri River.

Figure 4 shows the geographical configuration of Douala IV and V drainage basins, its streams and tributaries. There are more drainage basins in the Douala V Municipality (6) than in Douala IV municipality (3).This follows a computation of the Bifucation Ratio from stream orders in these basins to determine which areas of the municipality are more laible to floods occurrence. With an average bifucation ration of 2.5, Douala V is more subsestible to floods than Douala IV with a ratio of 2.3 for its three drainage basins. The analysis show that 1st and 2nd order streams pose more threats of flood to the population in both municipalities than 3rd, 4th and 5th order streams. Areas with a high drainage density are highly exposed to flooding events.

3.1.3 Urbanization and poor soil management practices

Urbanisation leads to the construction of impermeable surfaces of tard and concrete that reduces infiltration and increases runoff into nearby streams and rivers leading to floods. Landcover analysis from landsat images of Douala town processed [Figure 5], reveals that, a greater proportion of the land surface was covered by forest and other vegetation types, than buildup areas within which are habitat and infrastructures The vegetation cover form a defencive wall (natural buffers) against the catastrophic floods that affected the town during this period.

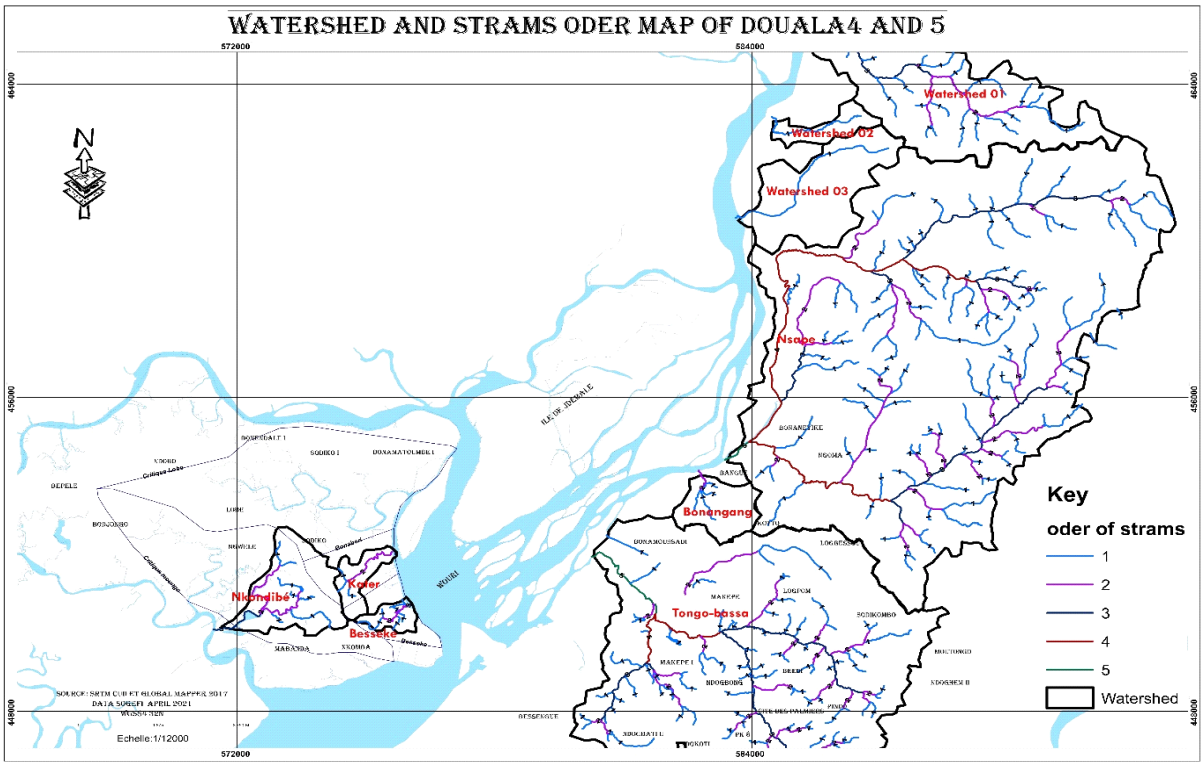

Figure 3: Hydrographic network of Douala IV and V

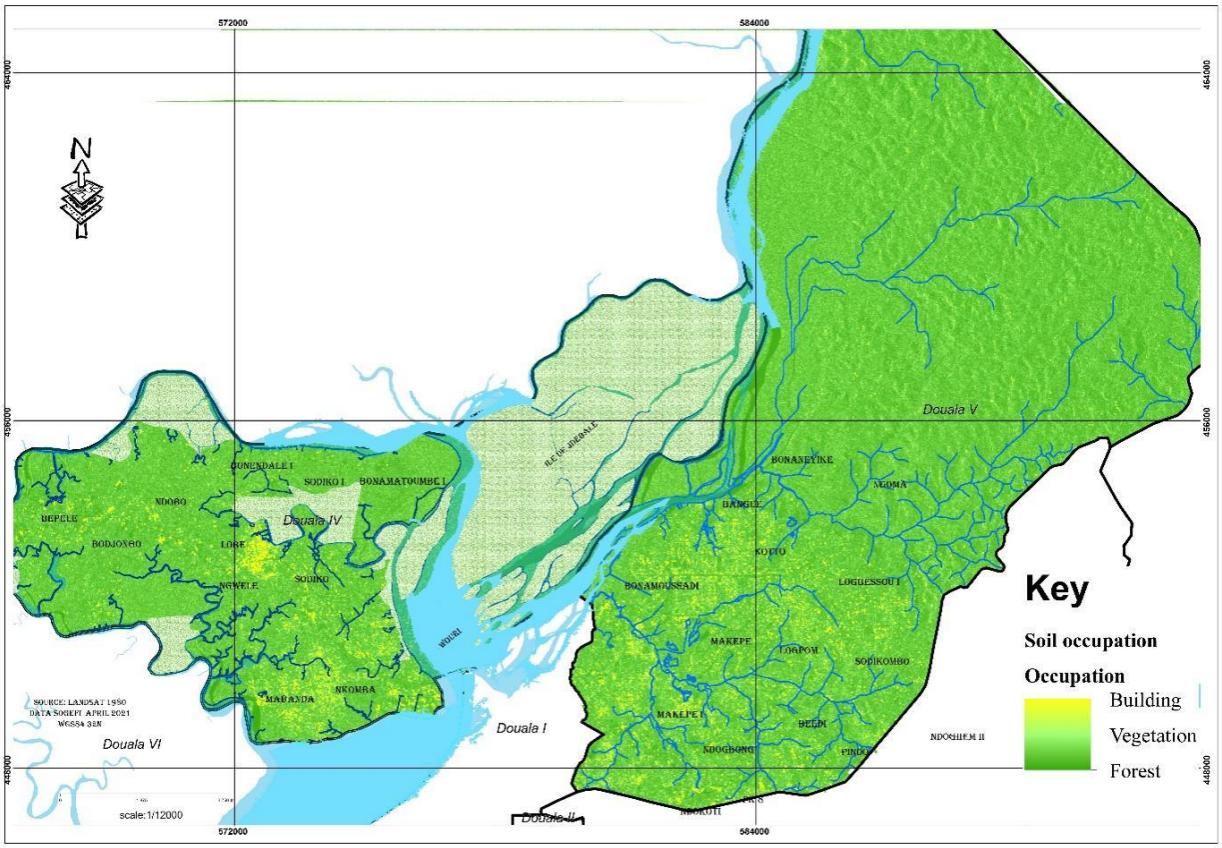

Figure 4: Situation of Land cover in Douala IV and V in 1980
Source: Landsat 1980

There has been a remarkable change in the buildup areas and vegetation cover of Douala IV and V over the past forty years (Figure 6). Within this period, urbanisation has been rapid characterized by population increase, increase in secondary and tertiary activities which led to the rapid degradation of the physical milieu. A rapid population increase, led to colonisation of the swamps and forest by the population for shelter, road construction works and installation of human socio-economic and cultural activities. This urbanization and destruction of vegetation increased population vulnerability to fllods in Douala.

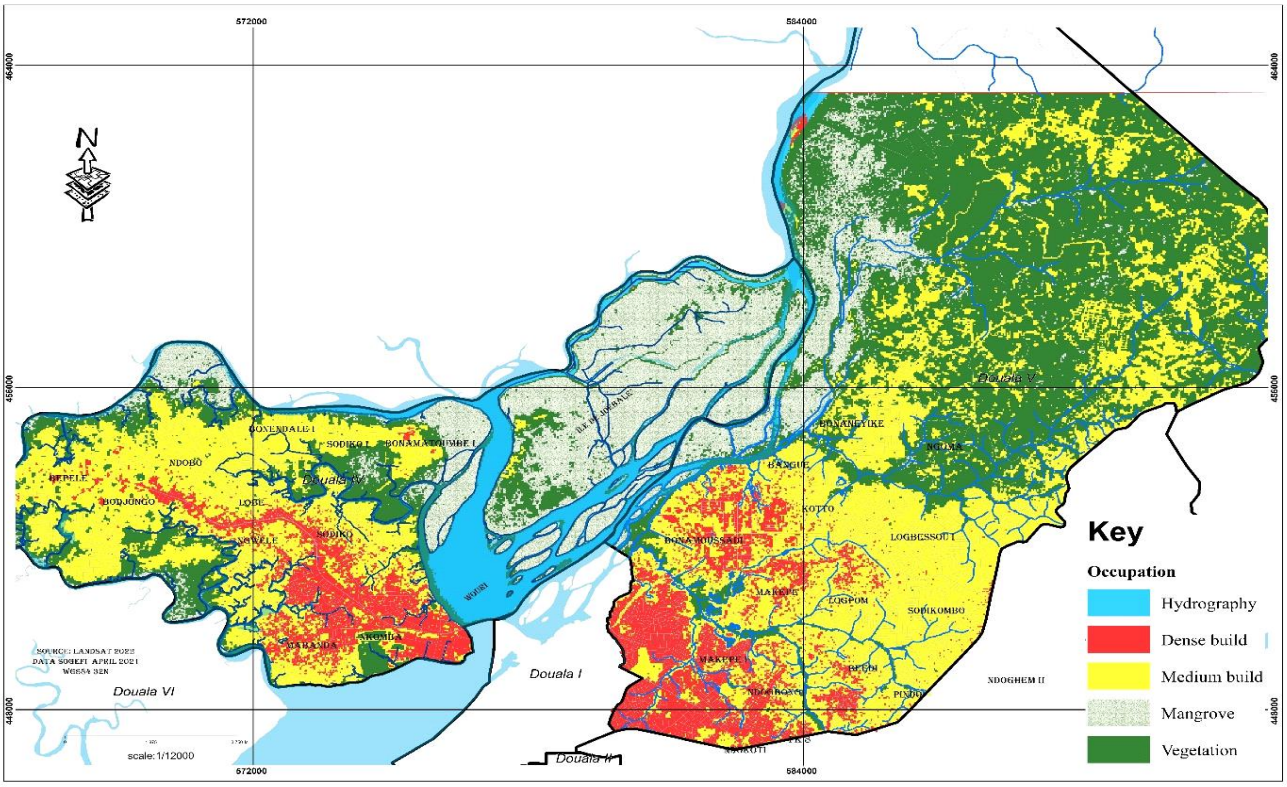

Figure 5: Situation of Land cover/Used in Douala V and IV in 2022
Source: Landsat 2022

Figure 6 shows the situation of land cover in Douala IV and V municipalities in 2022 marked by an increase in built up space and vegetation regression. Settlements have expanded as seen on the yellow and red coloured portions.The green areas covered by vegetation have regressed when compared to the situation in in 1980. The settlement areas marked by unpaved spaces, roofs and tard surfaces easily channel running water during heavy rains into streams with little infiltration into the soil. Growth of settlement adds presure on the environment. During heavy and prolonged rainfall, there is an increase in floods which adversely affect the settlement areas as seen on plate X.

A B

C

D

E

Plate X: Areas affected by flood in Douala IV and V
Source: Researcher 2021

Plate 7 shows imprints of waste dump in water ways by the urban dwellers in some quarters. When heavy rains occur leading to floods water cummulaes and damage human property and infrasture. human actions that increases flood risk in Douala town IV and V. Photo A shows a tractor removing laterite, dry ground and stones to fill wetland areas. Photo B shows drains filled with waste products disposed from habitats. In photo C plastic bottles droped by the population are washed by runoff leading to blockage of water passage. Photo D shows logs of wood from deforested lands and Photo E, garbages dropped along river banks.

3.2 Effects of flood in Douala IV and V

The effects of flood are many and varied and differ from one person and place to another. They include; loss of human lives and property, psychological effect, water pollution, destruction buildings and public infrastructures [Plate X].

A] Extention of flood water

B] Properties damaged

C] Contermination of water source [well]

D] Flooded home

Plate X: Effects of floods on population and property in Douala V

Source: Researchers (2021)

Plate X illustrates some effects of flood in Logpom (C and D) and Melangue (A and B) quarters of Douala V. In photo A floodwater has invaded many parts of Melangue quarter. Photo B shows buildings and property destroyed by floods at Logbom, In photo C a well for domestic water supply has been submerged by flood water, and a home in Photo D rendered inaccessible after flood water cumulation after 24 hours of heavy rainfall. These negative effects of flood necessitate the implementation of urgent adaptation strategies in Douala IV and V to control the situation.

3.2.3 Flood adaptation strategies in Douala IV and V

Fieldwork revealed several adaptation measures used by the Douala population to reduce flood effects. It was observed that, 49.3% of the population use piles of sand bags, 24.2% disposed car tires, 11.5% raised concrete walls as defencive barriers and mechanisms against flood water entry into their homes. Where these efforts have not succeeded many residents (15%) have moved out of these high risk zones to safer areas of Douala V such as Rail quarter in Bonaberi and Diedo (Table 1). In some situations, other stones have been used to raise house foundations, flower trees and bananas planted around homes and religious practices (prayers) performed with the hope of preventing flood damages.

Table 1: Flood adaptation measures

Measure	Frequency	Percentage	Cumulative Percentage
Alignment of disposed car tires	116	24.2	24.2
Relocation to safer zones	72	15.0	39.2
Piling of sand bags	236	49.3	88.5
Building of concrete walls	55	11.5	100
Total	479	100.0	/

Source: Researcher 2021

The management of floods involved several stakeholders. These are the Douala municipality, MINHDU, quarter and block heads and agents of the National Observatory on Climate Change (ONACC). These stakeholders periodically sensitize the population on the dangers of disposing waste or dirt in gutters. They also organize periodic clean up campaigns (hygiene and sanitation) in quarters located in risks zones. Clean up programs such as *« Douala clean city it's possible », piloted by the Douala City* council is aimed at educating the urban dwellers and visitors on the need for better environmental care and waste management (Plate X). *HYSACAM (the company responsible for household waste collection in Cameroon) is actively involved in keeping the city clean through waste collection and disposal to lessen the effects of floods when it rains.*

Plate X: The use of signboards by Douala Council as preventive measures by its population from disposal of dirt in Riverbanks

The National Observatory on Climate Change [NOCC] of Cameroon plays a vital role in coordination and implementation of actions and strategies geared towards mitigation of impacts of climate change on urban floods in Cameroon cities amongst which is Douala. Some of these measures are advocacy in indigenous knowledge application in flood prevention, community engagement through knowledge sharing and education of urban residents on flood preparedness and response.

3.1.4 DISCUSSION

This paper sake to show the influence of rainfall variability on flood occurrence, the implications of floods on the urban population and preventive strategies put in place by different stakeholders within the Douala IV and V municipalities to manage the situation. The findings showed that, rainfall varies from one year to another and month to another with implications on flood occurrence. Increase in the amount of rainfall makes the population more vulnerability to these events. With a coefficient of variations of 21.75% of rainfall for the period under study, Douala metropolis is liable to flood occurrence on monthly and yearly basis. This is in accordance with similar studies carried in Douala by Roméo *et al.*, (2017). In this findings the authors revealed that, in the soundings of the Douala International Airport the floods of June 2015 were characterized by heavy downpour, thunderstorms and high vertical integral water vapour - an indicator of intense stormy episodes marked by persistent instability in Douala during this period. According to Robert (2019) all coastal cities in the world today are experiencing climate variability and change with 4 out of 5 persons in East or Southeast Asia likely to be affected by a rise in sea level by 2030.

The present findings identify several determinants as influential in floods occurrence. Anthropogenic factors such as uncontrol urbanization, deforestation, haphazard occupation of water channels and poor waste management practices together with a dense hydrographic network and proximity of Douala to the Atlantic Ocean are key determinants of catastrophic floods in Douala. This finding is in concordance to the works of Bang *et al.*, (2017), Ndi (2018), Fauchereau *et al.*, (2003). Their study attribute population vulnerability to frequent flood episodes in Cameroon to unplanned urbanization, population growth, dense hydrography, deforestation, relief and the El Niño Southern Oscillation (ENSO). In African coastal cities Douala included rapid urbanization and overcrowding of poor populations in informal settlements along the coast exposes them to floods hazards and catastrophes.

This study also identified the outcomes of floods on the vulnerable populations. It was observed that catastrophic floods in Douala IV and V adversely affect urban agriculture, education and health services, habitats, water, property and valuable assets of the population. Studies done by Mwape (2009), Saleem *et al.*, (2013) and Gulsan *et al.*, (2016) have arrived at similar conclusions. Also, over 90 coastal cities in the United State of America currently experience chronic floods. The numbers are expected to double by 2030.

Adaptation strategies such as the raising of houses foundation, building of levees and embankments, use of sandbags and stones, cleaning and maintenance of drains to ease water passage are common practices in many cities affected by floods (Kundzewicz *et al*., 2002), structural measures such as the building of dikes or the straightening of river courses are most common flood defense practices even though it often leads to a false sense of security. In addition, the construction of traditional dikes, solid houses and on stilts, the use of impregnated mosquito nets, canoes, embankments, drains, rehousing and distribution of kits can reduce the impact of catastrophic flooding (Mena and Mbaiamdene 2024). Unfortunately, some of these adaptation measures have been appropriated by the Douala IV and V city dwellers yet ineffective as the population have a weak knowledge of the nature of risks affecting them. This paper proposes the clearing of drains, continuous dredging of the river Wouri and Dibamba that traverse Douala to help reduce flooding in the city.

The high vulnerability of the population, infrastructure, and services to the floods recorded in the Douala IV and V municipalities calls for the attention of stakeholders for action. This should be done through identification, zoning of flood zones, periodic alert, campaigns for non-deforestation, afforestation and reforestation of the mangroves along the littoral zone. As earlier mention, the mangroves contribute to stabilize the coastline and shelter it from storm. It is also of diverse benefit to the community with regards to their role in biodiversity preservation, energy supply, ecosystem service and resource base. In addition, this mangrove forests sequestrates carbon dioxide emission and other greenhouse gases from the atmosphere faced with climate change and its catastrophic effects to humanity.

CONCLUSION

The main objective of this paper was to examine how rainfall variability influences flood occurrence and population vulnerability within the Douala IV and V municipalities of Cameroon. It was observed that the rainfall pattern is unstable, unpredictable and varies within months and years. Rainfall fluctuation is the main triggering factor responsible for flood in Douala IV and V. Other drivers are anthropogenic (urbanization, deforestation, occupation of drains and poor waste management practices) and physical (a dense hydrographic network and the town's adjacent position to the Atlantic Ocean which predisposes it to catastrophic floods. High degree of flood vulnerability is observed on the population via loss of human lives, destruction of property and increase in the prevalence of water bone diseases such as typhoid. The different adaptation measures employ by the resident populations and stakeholders are inadequate to reduce flooding activities. Consequently, floods remain a concern in Douala. Good environmental practices such as civil education promotion, hygiene and sanitation, periodic cleaning of drains, campaigns against deforestation of the mangroves and afforestation, government investment on decentralization of waste collection and management will be productive in reducing the effects of floods in Douala. The implementation of all these remedial measures will not only ensure the safety of the vulnerable populations but also the protection of their activities.

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