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Floods in the Douala metropolis, Cameroon: attribution to changes in rainfall characteristics or planning failures?

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With urban populations worldwide expected to witness substantial growth over the next decades, pressure on urban land and resources is projected to increase in response. For policy-makers to adequately meet the challenges brought about by changes in the dynamics of urban areas, it is important to clearly identify and communicate their causes. Floods in Douala (the most densely populated city in the central African sub-region), are being associated chiefly with changing rainfall patterns, resulting from climate change in major policy circles. We investigate this contention using statistical analysis of daily rainfall time-series data covering the period 1951–2008, and tools of geographic information systems. Using attributes such as rainfall anomalies, trends in the rainfall time series, daily rainfall maxima and rainfall intensity–duration–frequency, we find no explanation for the attribution of an increase in the occurrences and severity of floods to changing rainfall patterns. The culprit seems to be the massive increase in the population of Douala, in association with poor planning and investment in the city's infrastructure. These demographic changes and poor planning have occurred within a physical geography setting that is conducive for the inducement of floods. Failed urban planning in Cameroon since independence set the city up for a flood-prone land colonization. This today translates to a situation in which large portions of the city's surface area and the populations they harbor are vulnerable to the city's habitual annual floods. While climate change stands to render the city even more vulnerable to floods, there is no evidence that current floods can be attributed to the changes in patterns of rainfall being reported in policy and news domains.

Keywords: floods; urban planning; climate change; population growth; rainfall; Douala

1. Introduction

It is estimated that by 2050, populations living in urban environments in the world would have doubled (Kreimer, Arnold, and Carlin 2003). The majority of this growth in urban population is expected to occur in developing countries. Much of the population drawn to cities and towns in the developing world in search of economic opportunities tend not to have the financial means to afford high quality housing and social amenities that urban centers offer. As a result, large numbers of migrants find themselves occupying fragile lands, in neighborhoods prone to a host of natural and social vulnerabilities (Kreimer, Arnold, and Carlin 2003). According to the United Nations Environmental Programme (UNEP), half the world's population lives within 60 km of the sea, and about three-

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quarters of all large cities are located on the coast (UNEP and UN-Habitat 2005). With projections of such coastal populations expected to grow in the future, coastal ecosystems are likely to come under increased pressure. In the same light, populations are likely to become vulnerable to sea level rise and other coastal hazards are likely to grow (Wilby and Keenan 2012).

Evidence has been put forward to support the view that the frequency and severity of some environmental disasters have been increasing over the last half century (Kreimer, Arnold, and Carlin 2003; Wilby and Keenan 2012). Examples of such disasters include (among many others) heatwaves, hurricanes and floods (Jevrejeva, Moore, and Grinsted 2012; Merz *et al*. 2010). Within the context of current global environmental changes, studies have investigated the frequency of occurrence of major water-related environmental disasters (outcomes of global climate change) at both the regional level (Brown, Kebede, and Nicholls 2011; Tchindjang *et al*. 2012; Tiepolo 2014) and at the global level (Hallegatte *et al*. 2013; Jevrejeva, Moore, and Grinsted 2012; UNEP and OCHA 2012; UNEP and UN-Habitat 2005). Such increases in the frequency and severity of urban disasters have been more or less worldwide, with cases of excess loss of life or property reported in all continents (Aderogba 2012; Clichevsky 2003). While the increase in the severity and occurrence of natural disasters may be worldwide, the responses to such disasters by local urban administrative bodies tend to differ between developed and developing countries. Kreimer, Arnold, and Carlin (2003) noted that although developed countries may register higher economic losses from disasters, there are usually systems in place to mitigate the losses for individuals, communities and municipalities. According to Klein, Nicholls, and Thomalla (2003) changes in storm patterns, sea level rise and floods could affect many of the world's coastal settlements, including many of the current 'megacities' with populations of over 8 million.

Flood concerns related to climate change stem from a perceived acceleration of the hydrological cycle, which hypothesizes that flood events are likely to occur more frequently (Huntington 2006; Trenberth *et al*. 2007). Precipitation intensity is expected to increase over much of the globe (Meehl *et al*. 2005; Morrison 2015). Whether or not they are related to global climate change, there are many different types of flooding and the categorization and definitions are used inconsistently in the literature. The Intergovernmental Panel on Climate Change report defines floods as: "the overflowing of the normal confines of a stream, or other body of water, or the accumulation of water over areas that are not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods" (IPCC 2012, 559). The unique characteristics of different flood types (pluvial, fluvial, etc.) have consequences in terms of the duration of the flood event, the lead times for flood warnings, their predictability and potential impacts (Chen *et al*. 2010).

Flooding is one of the most common natural disasters currently affecting large areas of the world. It has been rated as the most damaging natural disaster globally – in terms of its frequency, human cost and geographic reach, it is third only to storms and earthquakes (Wilby and Keenan 2012). According to Guha-Sapir, Hoyois, and Below (2014), there were 159 hydrological disasters (the general term encompassing floods and wet mass movements in the EM-DAT disaster database) in 2013 globally. This constituted by far the largest share in natural disaster occurrence (48.2%) in 2013, compared to meteorological disasters (storms), 32.1%; climatological disasters (extreme temperatures, droughts and wildfires), 10%; and geophysical disasters (earthquakes, volcanic eruptions and dry mass movements), 9.7% (Guha-Sapir, Hoyois, and Below 2014). In terms of cost, hydrological disasters accounted for 33.2% of total disaster victims (32 million victims), constituting about 46.5% of the total reported disaster deaths and 44.9% of total damages (Guha-Sapir, Hoyois, and Below 2014). The general global trend is that of an increase in climate-related (hydro-meteorological) disasters and associated economic damages (Leaning and Guha-Sapir 2013). An intensification of floods in existing humid areas of the world is expected, with significant implications for municipal, regional and national planning towards the mitigation of its impacts in sectors such as health (Few *et al*. 2004; Klein, Nicholls, and Thomalla 2003). The impact of flooding on urban spaces can be diverse – impacting "on the population, buildings, livestock, crops, and goods, as well as an indirect impact in human, economic, social, financial, political, and institutional terms" (Fogwe 2015; Tiepolo 2014, 25). In Africa, hydrological disasters represented 77.3% of all disasters, with floods attributed to huge losses of life and property in countries such as Niger, Kenya, Mozambique and Sudan (Guha-Sapir, Hoyois, and Below 2014).

In Cameroon, more than 30% of the population lives on the small strip (548 km) of its coastal zone, in major cities such as Douala, Limbe, Kribi, Tiko and Campo (Ajonina 2008). Douala is Cameroon's most populous city, the economic capital of the country, as well as the biggest economic and industrial center in the Economic and Monetary Community of Central Africa (CEMAC) region. Its population stands at about 2.1 million (i.e. approximately 11% of the total population and about 20% of the urban population in Cameroon), and is growing at an annual rate of approximately 5% compared to the national average of 2.3%. In the 2005 general population census, when the average population density of Cameroon was 37.5 persons per km^2, the littoral region had the highest density in the nation, of 124 persons per km^2, with much of the population concentrated in Douala (the administrative headquarters of this region, as well as the economic capital of the country) (INS 2011). The rate of population growth (fueled chiefly by immigration from other regions of Cameroon) and urbanization is high.

Flooding is a common feature of Douala, and incidences are reported almost every year in at least a few localities of the urban area (Tchindjang 2013; Tchindjang *et al*. 2012). Tchinjang (2013) reported that annually, an average of 5–10 floods occur in Douala, with the average of one death for every flood incident. Over the last 15 years however, 10 major incidences of flooding have occurred with significant human, material and psychological costs. The range of observed impacts attributed to climate change in Africa are many, and include impacts on rivers, lakes, floods, drought, terrestrial ecosystems, wildfire, marine ecosystems, livelihoods, health, economics and food production (IPCC 2014a). These impacts are not equally spread throughout the region, hence attribution requires defined proof on the role of climate change. Flood concerns related to climate change stem from a perceived acceleration of the hydrological cycle, which hypothesizes that flood events are likely to occur more frequently (Huntington 2006; Morrison 2015; Trenberth *et al*. 2007). For many regions and processes, there still exist gaps in data and studies to permit an evaluation of the role of climate change on a range of outcomes (IPCC 2014a). This study examines the relationship between key characteristics of one of the important climate variables – rainfall, and its association with floods in the city.

One of the first steps in the development of a resilient system for disaster prevention and management is an understanding of the inherent resilience of the system (Cutter *et al.* 2008). As recognized by Biesbroek *et al*., the choice of analytical lens used to analyze problems (such as climate change) "influences how barriers to adaptation are constructed and the intervention strategies proposed" (Biesbroek *et al*. 2013, 1011). The increase in the frequency of occurrence and damages arising from floods in Douala is being attributed to a range of causes – from the divine (God's will or punishment), to climate change (chiefly ascribed to an increase in the amount and intensity of rainfall) (Fonchingong 2013; MINEE 2009; MINHDU 2014; Urbanplan and CUD 2009). While this study is not equipped with, or designed for, investigating divine causation of an increase in the frequency of floods and its associated damages, questions about rainfall attribution can be investigated. To what extent can an increase in the frequency and severity of floods be attributed to long-term changes in rainfall patterns? Are there other factors which contribute or explain the phenomenon of floods in Douala? If so, what are these factors and how do they contribute to understanding the phenomenon of floods in the city?

2. Objectives

This study set out to achieve two main objectives.

- Examine the claim that climate change, as seen through changes in characteristics of rainfall, is responsible for the recurrent floods in Douala.
- Examine the contribution of other factors in explaining the recurrence of more intense and devastating floods in Douala.

This study is significant as it contributes to a nuanced understanding of how climatic factors or human behavior shapes the understanding and discussion regarding issues of environmental concern, in this case the frequency and magnitude of hydro-meteorological events such as flooding.

3. The study area

Douala (Figure 1) is Cameroon's most populous city, the economic capital of the country, as well as the biggest economic and industrial center in the CEMAC region. Its

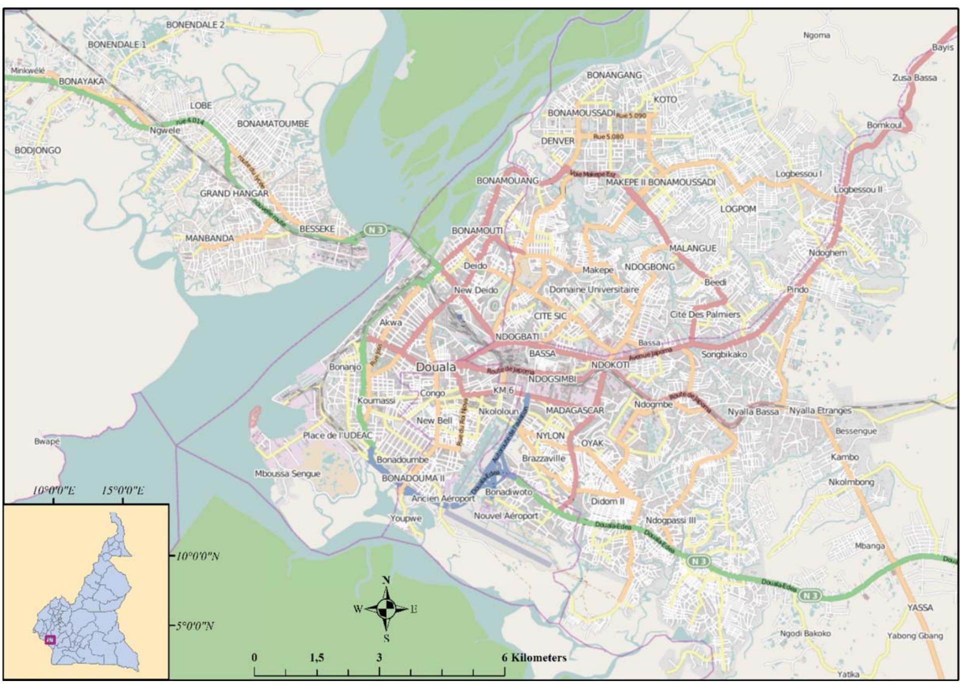

Figure 1. The location of Douala, Cameroon.

population stands at about 2.1 million (i.e. approximately 11% of Cameroon's population and about 20% of the urban population), and is growing at an annual rate of approximately 5% compared to the national average of 2.3%. In the 2005 general population census, the average population density of Cameroon was 37.5 persons per km^2. The littoral region had the highest density in the nation, of 124 persons per km^2, with much of the population concentrated in Douala (the administrative headquarters of this region, as well as economic capital of the country) (INS 2011). The rate of population growth (fueled chiefly by immigration from other regions of Cameroon) and urbanization is high.

The city is divided into six districts, five of which are urban and one, rural. The urban districts include: Douala 1 (Bonandjo), Douala 2 (Newbell), Douala 3 (Logbaba), Douala 4 (Bonassama) and Douala 5 (Kotto). Douala 6 (Monako) is the rural district. Douala, a port city on the Atlantic coast, is located at the mouth of River Wouri whose average inter-annual discharge is estimated at 311 m^3/s. The Wouri basin on which Douala is located has an estimated size of approximately 11,700 km^2, has a low topography (compared to the rest of the region), and is separated by numerous estuaries. The soils are ferralitic, with substantial inputs of silt brought in and deposited by the Wouri and other river systems as they reach the low-lying basin adjoining the ocean.

According to the Douala City Council (CUD), about 16,300 hectares of land have been urbanized since the 1960s − averaging about 326 hectares per year. Approximately 64% of the urban area is occupied by dwellings, of which about 24% are unplanned. Given the rate of demographic growth in the city, and demand for new land, it is estimated that by 2020, up to 13,000 hectares of new land may be required to meet the needs for housing and other urban services in Douala. By 2025, it is estimated that approximately 31,000 hectares may be required to meet this need. The rapid rates of demographic increase and urbanization far outpace the rates of development of social and economic infrastructure in the city. The result is increased pressure on existing infrastructure (roads, sewers, schools, hospitals, etc.). The lag between the city's demographic and spatial growth and its development of infrastructure can be exemplified by the state of its road infrastructure. Douala has about 1,800 km of road tracks, of which only 26% are tarred.

Located at 4.0500° N, 9.7000° E, Douala has an equatorial climate characterized by annual average rainfall of 3,000−4,000 mm, mean temperatures of 29−30 °C and high relative humidity of up to 75%. The annual rainfall profile is equatorial (rainy throughout the year) and mono-modal (has one annual peak) with the months of June to October receiving mean monthly rain inputs of more than 400 mm (Figure 2). The city of Douala is situated on an estuary where several rivers drain into the Atlantic Ocean. The main rivers in the sub-basin that comprise sections of the Douala basin (an area of about 11,700 km^2) are the Mungo, the Wouri, the Dibamba and the Sanaga. The Wouri basin, together with the Wouri River, is the most important of these coastal sub-catchments, with an inter-annual mean flow of about 311 m^3/s. The Dibamba basin is the second most important, given that is home to a large population of the city. It is located to the south of the Wouri basin, and its main hydrological feature, the River Dibamba drains a catchment area of about 2,400 km^2.

Given the location of the city in an estuary of many rivers, the soils are rich in silt deposited by these rivers. Douala is a low-lying plain with altitudes of 20 m or less (see Figure 3). Altitudinal profiles show that many areas in the west of the city (Profile 1) have substantially low altitudes (less than 10 m above sea level) which make them prone to inter-tidal floods and water level rises generated by low to moderate rainfalls. These

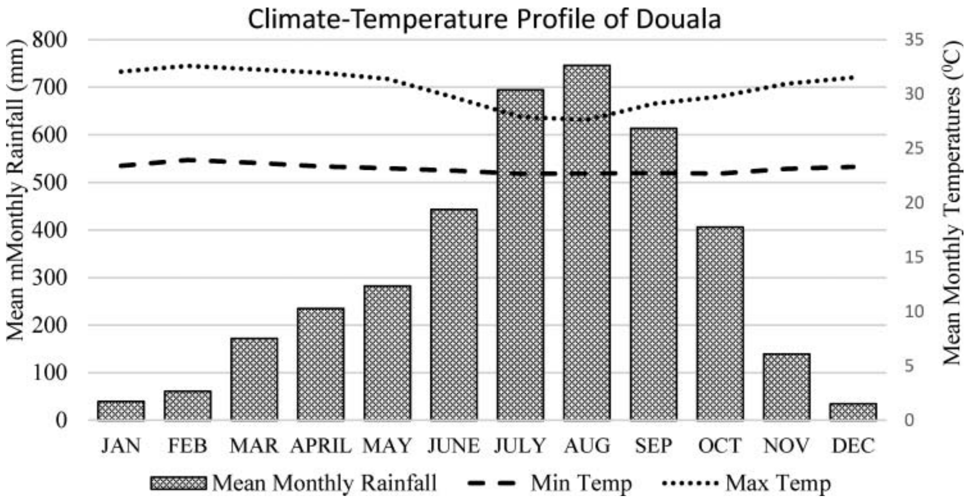

Figure 2. Rainfall–temperature profile of Douala (data source: National Meteorological Institute, Douala).

include the Bonaberi and Bodjongo communities where some of the most damaging outcomes of floods tend to be reported almost yearly. The same can be said of areas in the south-west (Profile 5) and south of the city (Profile 4).

Central parts of the city and their eastern extensions (Profile 3), as well as central sections of its northern extension (Profile 2), have comparatively higher elevations of between 15 and 20 m. These include the communities of Bonanjo, Akwa, sections of Deido, Bassa and Nyalla. These relatively higher elevations make these sections of the city comparatively safer from floods (Table 1). The flat and low-lying site of Douala, together with its proximity to the sea, favors the presence of high moisture content in its soils. Increasingly, the role played by soil moisture content in the generation of floods is being more fully appreciated (Shaw *et al*. 2010).

4. Nature of floods in Douala

Two main factors determine the nature of floods experienced in Douala:

(1) The equatorial and coastal location of Douala, which determines its mono-modal equatorial rainfall regime. This rainfall regime is characterized by a short dry season of about four months, and one long wet season of about eight months. Rainfall tends to be continuous year round with the difference between the rainy and dry seasons being a significant increase in the amount of precipitation in the rainy seasons (see Figure 2). Most of the floods occur between the months of June and October when the average monthly rainfall is at or above 400 mm (Appendix 1). Pluvial flooding is common during this period. Pluvial or surface flooding is caused when heavy rainfall creates flood events independent of overflowing water bodies. Unlike fluvial floods, which would affect river banks and floodplains, pluvial floods can occur anywhere in the urban area.

(2) The system of land use in Douala, which has long suffered from lack of concerted regulation, also contributes to flooding in the metropolitan area. Such land uses have not taken consideration of minimizing the potential of natural hydrological

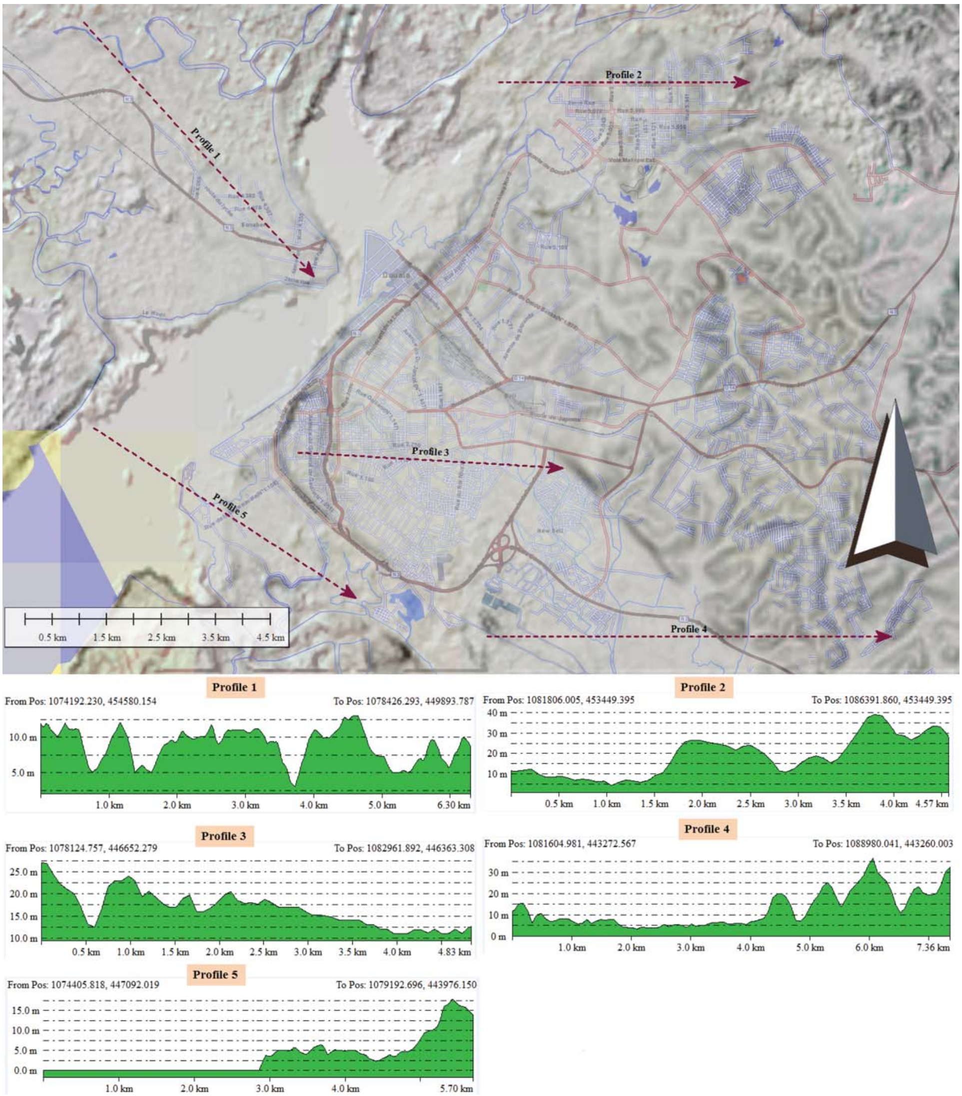

Figure 3. Digital elevation model for the Douala City area, showing altitudinal profiles from which locational characteristics of major activities are derived.

Table 1. Altitudinal distribution of human activities in Douala (a result of combining a digital elevation model with field sampling).

Altitudinal range (m)	Area (km^2)	Range %	Cumulative %	Characteristics
0–20	49	48.51	48.51	Dense slums, commercial and port area
20.1–40	35	34.75	83.21	Modern planned residences and industrial concentrations
40.1–60	16	15.84	99.05	
>60	1	0.99	100.0	Mainly industrial establishments

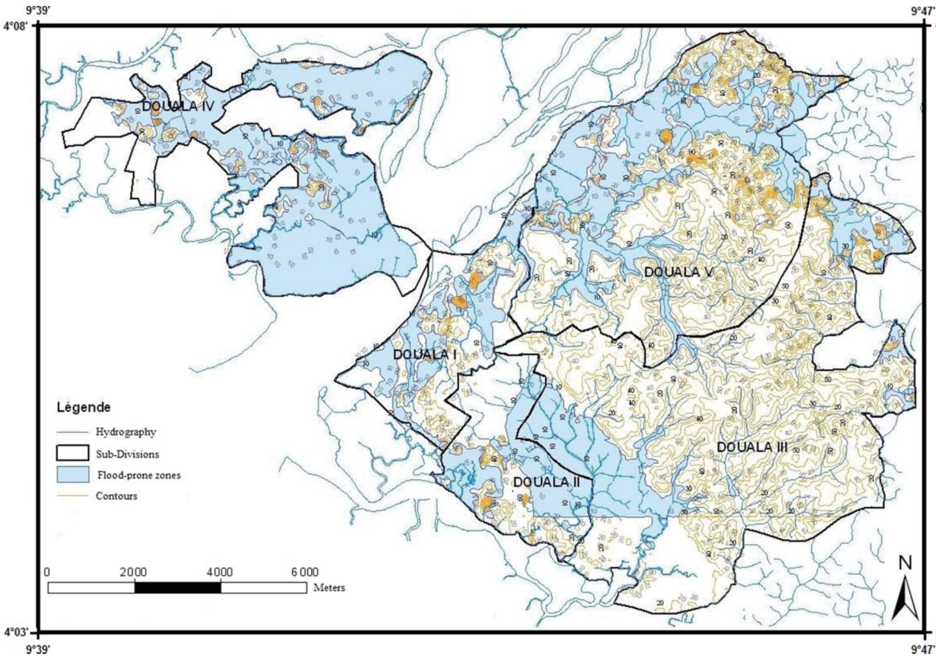

Figure 4. Flood-prone areas in the different districts of the Douala metropolitan area.

structures to channel inputs of water away from the city area. The potential of hydrological channels moving water from the city is hampered by the construction in habitable areas close to streams and river banks, and the use of hydrological structures as dumpsites for household and other wastes. These, combined with the rapid generation of flows over the urban surface, are the physical processes that combine to render the urban hydrology incapable of sufficiently conveying water outside the city area. Fluvial floods are characterized by the probability and intensity of high river flows that depend on the physical processes of flood generation (Merz *et al*. 2010). In Douala 5, many of the areas of flood risk are located around stream and river banks (Figure 4).

In a location such as Douala where favorable conditions for both fluvial and pluvial flooding are met, it is difficult to clearly distinguish between pluvial or fluvial causes for each flood event. Here, we find a case where intense equatorial rainfalls contribute to generate pluvial flooding – a condition that is helped by the stream and river channels whose ability to channel water out of the city area has been diminished. In such a situation, the concurrence of pluvial and fluvial flooding can aggravate their (individual) potential damages (Chen *et al*. 2010).

The majority of the flood-prone areas occur in the north, south-east and few in the west of the city, where closeness to the sea and the flat topography are determining factors (Figure 4). The flood-prone areas separate the planned or modern central (Akwa, Bonanjo, Bonapriso) and the peripheral quarters (Bonamoussadi, Kotto) from the unplanned slums of Koumassi and Besseke valley, as well as Makepe Petit Pays, respectively. The modern central and peripheral quarters (flood-free) have grown from the planned areas of settlement that were inherited from the colonial era. The modern city administrators have followed up with the development of modern residential quarters on flood-free surfaces of Makepe II, Kotto and Bonamoussadi. With demographic growth and unplanned settlement building, the development of slums in areas such as Bali-Koumassi, Tongo Bassa, Bonaberi and the Mbanya basins has transformed the city's hydrographic network. Three main outcomes of such slum developments can be observed: (1) many sections of the stream and river channels have been reclaimed for home construction and rendered narrow, and in some cases; (2) stream profiles have been altered, inhibiting the free flow of water; and (3) waste disposal into stream valleys is choking sections of it, constraining the surface water circulation in an already predominantly flat land.

5. Materials and method

5.1. Rainfall data and analysis

A complete record of daily rainfall data for Douala is derived from the Department of National Meteorology in Cameroon. These data were recorded at the Douala International Airport from 1951 to 2008. Unfortunately, we could not obtain daily rainfall data beyond 2008 (i.e. from 2009 to the present). Nonetheless, we consider the 57 years of data covering the period 1951−2008 to be sufficient in providing insights into our examination of key variables in this study. From these data, monthly and annual values are derived for specific analysis. Four rainfall characteristics are analyzed for the city of Douala. These include: rainfall anomalies, trends in the rainfall time series, daily rainfall maxima and rainfall intensity−duration−frequency (IDF).

5.2. Rainfall anomalies

An anomaly of a meteorological variable (rainfall, temperature, relative humidity) is the deviation of the value of that variable in a given region from the normal (mean) value for the same period. The use of anomalies in characterizing floods is a well-established concept for meteorological and hydrologic floods (Du *et al*. 2013; Espinoza *et al*. 2014). Meteorological floods are classified based on anomalies in precipitation, while hydrologic floods are characterized in terms of deviations of streamflow or river water depth from historical norms. The observable impacts of any of these two floods (meteorological or hydrologic) give rise to a third category of floods − agricultural floods. Agricultural floods and urban floods are defined by their impact on agricultural production and products (farms, crops, livestock and irrigation infrastructure) and on the urban environment, respectively. An anomaly of a climate variable will tend to affect a community or society at the same time as other factors (such as limited investment in infrastructure, poor land-use planning and land management, inappropriate land use, conflict and others). On this basis, we have not limited our analysis on the examination of rainfall anomalies alone. Rainfall anomalies are analyzed within the context of other flood-relevant rainfall characteristics (trends of monthly and annual rainfall totals, number of rain days, frequency of extreme rainfall), while the climatic factors (all rainfall variables) are analyzed within the framework of other important variables in socio-economic, demographic and city planning dynamics.

5.3. Testing for trends in the time series

To explore characteristics of rainfall in Douala, we examine the mean monthly distribution of rainfall and trends in the anomalies of rainfall time series. Mann−Kendall trend test is used to examine trends in the frequency of total annual rainfall, high rainfall episodes, as well as the annual number of rain days. Mann–Kendall trend test is a non-parametric trend test that is used to determine if a trend can be identified in a series, even if there is a seasonal component in the series (Tomozeiu *et al*. 2000). The test requires that the observations are independent (that the correlation between the series with itself with a given lag should not be significant). As a result, we computed the autocorrelation of the time series in each case before applying the trend test. The significance of the test statistic, Kendall's tau (τ) is used to determine the presence of a trend where the X variable is time (T). No distributional assumptions are required to test Kendall's tau (Landau and Everitt 2004). In these tests, we compute Kendall's tau which is a measure of the correlation (strength of the relationship) between x (time) and y (rainfall anomaly, days and monthly amounts) variables. Kendall's tau is carried out on the ranks of the data and its output values range from -1 to $+1$. Like other correlation routines, positive correlation indicates that the ranks of both variables increase together while negative correlation indicates that as the rank of one variable increases the other one decreases. The two-tailed alternative of the Mann–Kendall trend test ($\alpha = 0.05$) was used based on the following hypothesis:

H_0: $\tau = 0$, there is no trend in the series (values are independent, identically distributed)
H_a: $\tau \neq 0$, there is a trend in the series (monotonic, not necessarily linear trend)

5.4. *Testing for breaks in the time series*

Homogeneity tests, using Pettitt's test statistic, are used to examine whether the time series is homogeneous over time, or identify periods at which change occurs (Pettitt 1979). Homogeneity tests involve a null hypothesis that a time series is homogenous (exhibits no major shifts) between two given times (Kang and Yusof 2012). There are many possible alternatives to the null hypothesis. These are built on the probability that the series may exhibit shifts over time as a result of change in distribution, changes in average values over a set of years, or the presence of a trend (Kang and Yusof 2012; Tomozeiu *et al*. 2000). The Pettitt's test is a non-parametric tool that requires no assumption about distribution of the data (Pettitt 1979). The Pettitt's test is similar to the tank-based Mann–Whitney test that allows identifying the time at which the shift occurs. The test statistic for the Pettitt's test is K and the p-values (computed using 10,000 Monte Carlo simulations) for the test are computed at $\alpha = 0.05$. The hypotheses for the Pettitt's test used in this study are as follows:

H_0: Data are homogeneous (there is no period at which change is detected in the data)
H_a: Data are not homogenous (there is a period at which change is detected in the data)

5.5. *Daily rainfall maxima*

Floods can be caused by episodes of extreme rainfall, making the consideration of rainfall maxima in flood assessment important (Shaw *et al*. 2010). According to Shaw et al (2010), while high values of annual and monthly precipitation may be useful for a range of flood studies, in themselves, they do not directly give rise to floods. Instead extreme daily rainfall events can be directly associated to flooding events. As a result, high rainfalls of shorter durations (in our case, a 24-hour period) that are useful correlate with respect to the formation of floods (Shaw *et al*. 2010). An observation of the frequency of daily precipitation maxima for the period of study is presented in Figure 6. For this study, daily precipitation maxima are defined as daily precipitation inputs of more than 100 mm. To further examine extremes within the defined threshold, we divided precipitation above 100 mm into two groups: 100.01–125 mm and >125 mm.

5.6. Rainfall intensity–duration–frequency (IDF)

Rainfall intensity, or the rate of rainfall, indicates the amount of rain that falls over a period of time of interest. It is usually presented in unit of rainfall measure per time scale of interest. High rainfall intensity indicates that it is raining hard or intensely – more rain is falling per unit of the time scale of interest, and vice versa. Rainfall duration refers to how many hours it rained at that intensity. In the context of flooding risk and management, rainfall duration refers to the time of interest for water to accumulate and potentially constitute a flooding risk to an area of interest. Rainfall frequency denotes how often that rain storm repeats itself. This refers to the average probability that an extreme rainstorm giving intense rainfall over a selected period of time will happen again (McCuen 1989). The return period of a rainstorm defines the average length of time between rainstorm events with the same volume and duration (McCuen 1989). One of the most common methods of developing IDF curves is to use Gumbel's extreme value distribution to fit the annual extremes rainfall data. The Gumbel probability distribution is defined as:

$$x_i = \mu_z + K_T \sigma_z \tag{1}$$

where x_T represents the magnitude of the T-year event, K_T is a frequency factor depending on the return period, T, μ_z and σ_z are the mean and standard deviation of the annual maximum series. The exceedance probability refers to the probability that a rainstorm event of a specified volume and duration will be exceeded in one time period – usually assumed to be a year (McCuen 1989). The relation between the exceedance probability (p) and the return period (T) is: $p = 1/T$. Drawing from the relationship in Equation (1), Table 2 gives selected combinations of T and p.

Rainfall intensity and duration are examined using rainfall IDF curves. Rainfall IDF curves are derived from the statistical analysis of rainfall events over a period over time (in our case, 1971–2008) and used to capture important characteristics of point rainfall. IDF curves are useful for gathering regional rainfall information required for a range of rainfall and storm management tasks by both water engineers and policy-makers especially at the municipality scale (McCuen 1989). Site-specific curves represent intensity–time relationships for specific return periods from a series of storms (Langousis and Veneziano 2007). IDF curves relate storm duration and exceedance probability (frequency) to rainfall intensity, which is assumed to be constant over the duration. The inter-dependency between i (cm/hour), D (hour) and T (year) represented in

Table 2. Selected combinations for return periods (T) given exceedance probabilities (p).

T (yr)	p
2	0.05
10	0.10
100	0.01

the IDF curve is as follows:

$$i = \frac{kT^x}{(D + a)^n} \tag{2}$$

where i – intensity (mm/hour), D – duration (hours), k, x, a, n – are constant for a given catchment. The frequency is expressed in terms of return period, T, which is the average length of time between rainfall events that equal or exceed any given magnitude (Equation (2)). Interpreting an IDF curve involves intersecting the duration of the storm (x-axis) to the rainfall intensity (y-axis) to know the return period of that storm (the curves in the graph). For example, a 10-minute precipitation with intensity of 200 mm/hour will have a return period of 10 years (Figure 8). Data used to develop the IDF curve for the period 1971–2008 were obtained from the National Meteorological Institute in Douala, Cameroon.

5.7. Secondary sources of data

The state body in charge of collecting and disseminating demographic data in Cameroon is the Central Bureau for Censuses and Studies of Population (in its French acronym, BUCREP) (INS 2011; MPC, INS, and BUCREP 2013). This body operates under the jurisdiction of the National Institute for Statistics (INS), in turn within the Ministry of the Economy, Planning and Regional Development (MINEPAT). Since the 1970s, three general censuses of population and habitats have been carried out (1976, 1987 and 2005). Results of the third comprehensive census are compiled in several volumes of *le Troisième Recensement Général de la Population et de l'Habitat (3ème RGPH)*. These volumes contain detailed information on demographic dynamics in Cameroon, ranging from the national to the fourth level administrative units. Besides reporting the results of the 2005 census, the information also compares changes observed between the censuses of 1976, 1987 and 2005 (MPC, INS, and BUCREP 2013). The data from the above censuses are used in this study to investigate alternative explanations to the situation of floods in the study region. Examples of such data used in this study include: regional demographic trends; distribution of roads and conditions of access to habitats; and the condition of habitats occupied by populations.

In a bid to identify key development challenges for the Douala Urban Council (CUD) and develop short- to medium-term plans for addressing them, the CUD undertook a study of the council area in 2013. This study, the *Plan Directeur d'Urbanisme de Douala a l'Horizon 2025* reported some of the key socio-economic and environmental challenges faced by the council (Groupe Huit-AS Consultants and DEPUDD-CUD 2013). The report also quantified the availability and demand for infrastructure, as well as living spaces, in Douala both within the time of the study as well as projections up to 2025. For this study, data on the availability of road infrastructure, habitable land, as well as the condition of these resources in the near and medium term, are derived from the *Plan Directeur d'Urbanisme de Douala a l'Horizon 2025* (Groupe Huit-AS Consultants and DEPUDD-CUD 2013). Other data, such as the spatial changes of population settlement in Douala, are derived from the archives of the CUD.

5.8. Digital elevation model

The data are derived from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2) on 17

October 2011. The ASTER DEM is a tiled 1.5 arc-second per pixel, with west longitude = 9° 37' 41.5579″ E, north latitude = 4° 07' 15.5321″ N, east longitude = 9° 52' 03.1363″ E and south latitude = 3° 56' 49.7094″ N. To characterize the distribution of land uses and socio-economic activities in the study area, five altitudinal profiles are used (see Figure 3). Land uses and habitat conditions for each transect are matched against the elevation of the area, permitting an understanding of which land uses and habitation types are characteristic for different elevation zones (Table 1).

6. Results

6.1. Examining rainfall as a climate attribution to floods

6.1.1. Trends in total annual rainfall and rainfall anomalies

Annual total rainfall for Douala has witnessed a decline from 1951 to the present (Figure 5). An analysis of the major phases of this decline reveals two main phases (Figure 5). The decline in annual total rainfall observed in Figure 5 is consistent with reported changes in annual precipitation over land (1951−2010) observed for equatorial regions of Africa by the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2014a). The negative tendency in annual rainfall time series is also clearly mirrored by the trend of annual anomalies. Generally, negative rainfall anomalies have characterized the last 30+ years in Douala.

6.1.2. Results of the Mann−Kendall trend tests for rainfall variables

Table 3 displays results from the Mann−Kendall trend test for annual rainfall anomalies. The results show that the computed p-value is lower than the significance level $\alpha = 0.05$. Consequently, we reject the null hypothesis (H_0) that there is no trend in the annual anomaly of rainfall, and fail to reject the alternative hypothesis (H_a) that there is a trend in the series. In the same light, we reject the null hypothesis that there is no trend in the monthly rainfall series and the number of rain days per year. The alternative hypotheses

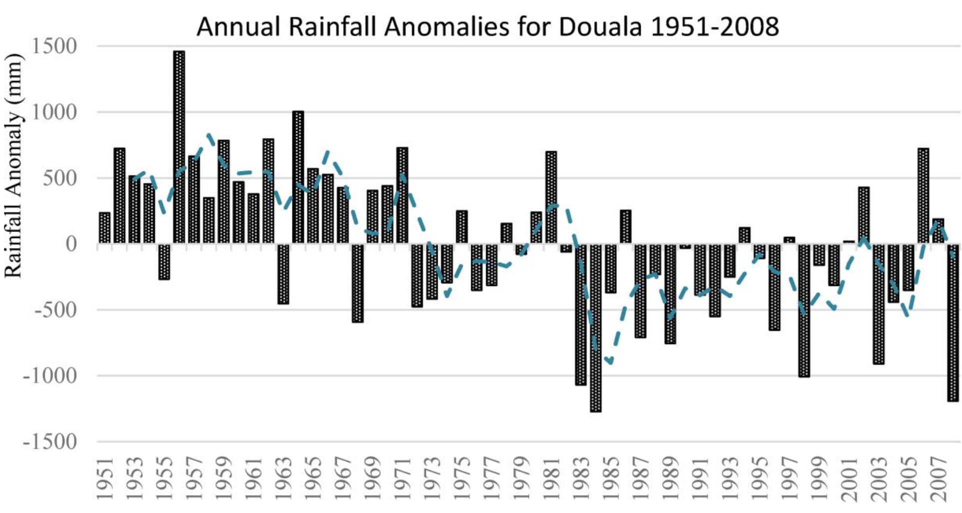

Figure 5. Annual rainfall anomalies for Douala with a four-year moving average.

Table 3. Results of Mann–Kendall's trends tests for annual rainfall anomalies, monthly rainfall and number of rain days.

Statistic	Annual anomaly	Monthly rainfall	No. of rain days
Kendall's tau	−0.347	−0.051	−0.214
S	−573.000	−12,220.000	−351.000
Var(*S*)	22,223.667	37,541,969.333	22,180.333
p-value (two-tailed)	0.000	0.046	0.019
Alpha	0.05	0.05	0.05

that there are trends are accepted for both tests at *p*-values of 0.046 and 0.019, respectively, as well as $\alpha = 0.05$ (Table 3). The negative Kendall's tau values for all variables indicate negative trends.

6.1.3. *Tests for homogeneity in the series*

Figure 6 shows the results of the homogeneity tests based on the application of Pettitt's approach. A significant downward shift in total annual precipitation is detected at the end of the 1970s and the beginning of the 1980s ($p \leq 0.01$ at $\alpha = 0.05$). This shift represents a change in mean annual rainfall from mu1 = 4,325 mm to mu2 = 3,608 mm. While total annual rainfall has tended to increase since the mid-1980s, the mean input still remains well below the pre-1970 levels.

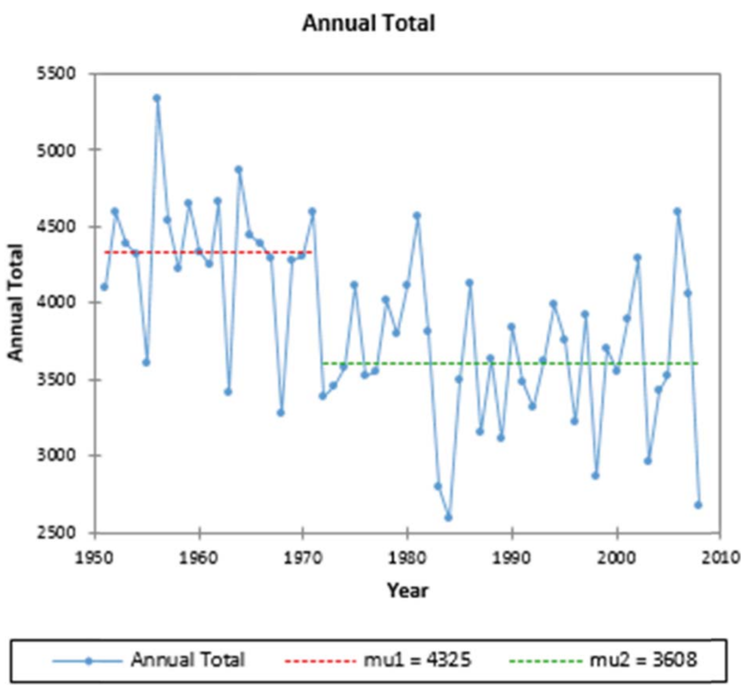

Figure 6. Results of the homogeneity tests showing the period of change in the annual total rainfall time series.

Table 4. A summary of homogeneity tests for annual total rainfall, number of rain days and monthly rainfall.

Statistic	Annual total rainfall	No. of rain days	Monthly rainfall
K	565	318	13,000
t	1971	1982	1971
p-value (two-tailed)	<0.0001	0.060	0.090
Alpha	0.05	0.05	0.05

While the null hypothesis of the total annual rainfall data being homogenous is rejected in favor of there being a period in which there is a break in the time series, the case is different for the other two variables. The test fails to reject the null hypothesis (H_a) that the data for number of rain days and monthly total rainfall are homogenous with $p = 0.06$ and 0.09, respectively, as well as $\alpha = 0.05$ (Figure 6, Table 4).

6.1.4. *Increase in the frequency of extreme daily rainfall*

The annual trend of extreme daily rainfall in Douala is presented in Figure 7. Mann–Kendall's trend tests of the series reveal that there is no significance in the trends. Kendall's tau for daily rainfall events of 100.01 to <125 mm and >125 mm are 0.088 (with a p-value of 0.432) and -0.182 (with a p-value of 0.091), respectively, both at $\alpha =$ 0.05. This test therefore fails to reject the null hypothesis, H_0: $\tau = 0$, that there is no trend in the series. The alternative hypothesis, H_a: $\tau \neq 0$ that there is a trend in the series is rejected for both daily rainfall events of 100.01 to <125 mm and >125 mm. The increasing intensity of recurrent floods in Douala is therefore not a result of an increase in the frequency of extreme daily rainfall events. If anything, the number of days with intense precipitation is decreasing each year (even though the trend is not statistically significant – Figure 7).

6.1.5. *Rainfall intensity, duration and frequency*

Based on the IDF curve (Figure 8), the maximum intensity of rainstorms, with a duration of 5 minutes and a probability of occurring once every 2 years is 205 mm/hour, once every 5 years is approximately 300 mm/hour; once every 10 years is approximately 375 mm/hour. Higher rainstorm intensities of between 440 and 600 mm have a probability of occurring once every 20 years to once every 100 years. The intensities decline with duration to 37–63 mm/hour for rainstorms that can last up to 180 minutes (Figure 8). These rainfall intensities indicate targets for which Douala city council officials can base the design and investment on rainfall-related infrastructures.

In relation to infrastructure planning, there is always a need to balance the cost of designing infrastructure to cope with extreme conditions, and the probability of occurrence of such conditions. Cost constraints limit the ability for planners to invest in drainage systems that can handle the most extreme of rainstorm flood risks observed in the IDF analysis. Municipal governments and administrators therefore tend to invest in the development of drainage systems that can handle 'acceptable' levels of extreme rainfall. While the concept of acceptable levels of extreme rainfall that can result in flood damage is relative and context specific, most municipalities tend to design stormwater

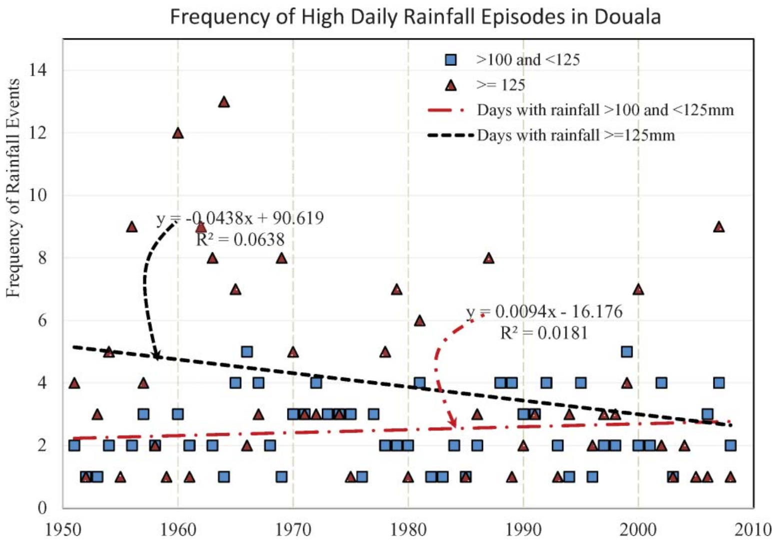

Figure 7. Frequency of extreme rainfall events in Douala (1951–2008).

systems to cope with a minimum of 5–10 year storms. Such systems may include structures such as stormwater sewers, dams and bridges, road culverts and other drainage systems. Guidelines on which return periods to consider when designing critical urban infrastructure are not fixed in stone. Generally, the design and siting of long-term strategic infrastructure such as power stations, major roads and bridges tend to examine and take consideration of the return periods of higher rainfall intensities and their associated flood-related vulnerabilities to communities.

6.2. *Non-rainfall-related causes – demands and challenges of city planning*

6.2.1. *Rapid demographic increase*

The current population growth of Douala stands at about 3.46% per annum (Figure 9). It is estimated that every year, approximately 100,000 migrants settle in the city of Douala.

Cadastral, infrastructural and other essential planning tools to accommodate the rapid increase in the population of Douala have either been lagged behind population growth or been insufficient to meet the rapid expansion of the city limits over the last half century. The outcome has been the unlawful and unplanned occupation of urban space as the city extended its outer limits to adjacent lands. On the ground, this expansion is characterized by a gentrification of locations that are safe from disasters such as floods by rich persons and businesses, and the occupation of flood-prone areas (including swamps and floodplains of many rivers that run through the city) by the poor. Among the many poor who occupy the flood-prone areas, are the late arriving immigrants from different regions of the national territory (Ngangue 2013). While the expansion of urban space can be evident over different periods over the last century (Figure 10) according to the CUD, two main phases of spatial expansion of the city can be distinguished from 1960 (when Cameroon attained independence) to the present (Ngangue 2013).

The first phase in which the city grew around an initial nucleus of colonial era neighborhoods: such as Joss (administrative and residential district), Akwa (mostly

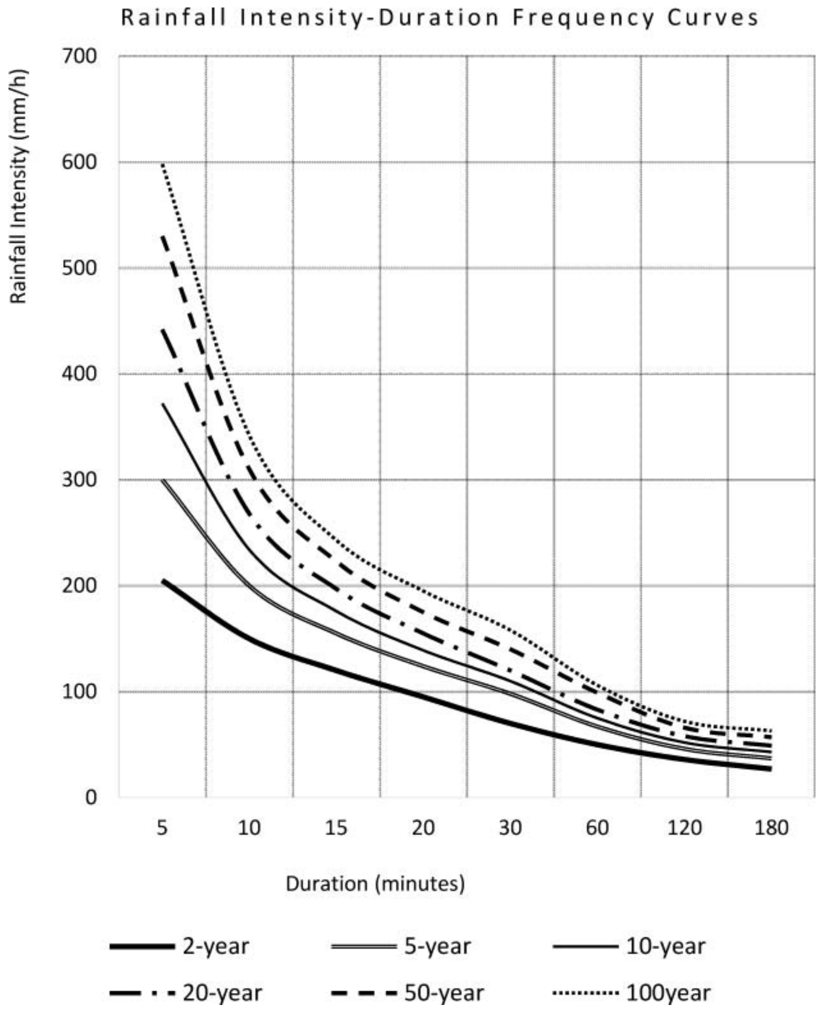

Figure 8. Rainfall intensity, duration and frequency curves for Douala (1971–2008) computed by the National Meteorological Institute in Douala, Cameroon.

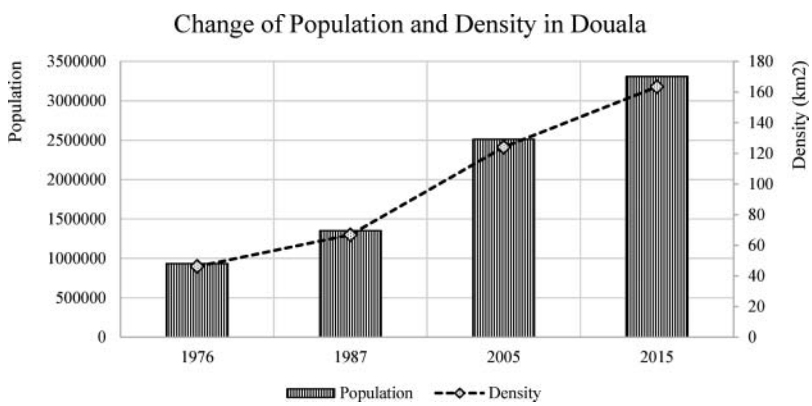

Figure 9. Population changes in Douala during the last three censuses and projections for 2015 (data source: BUCREP).

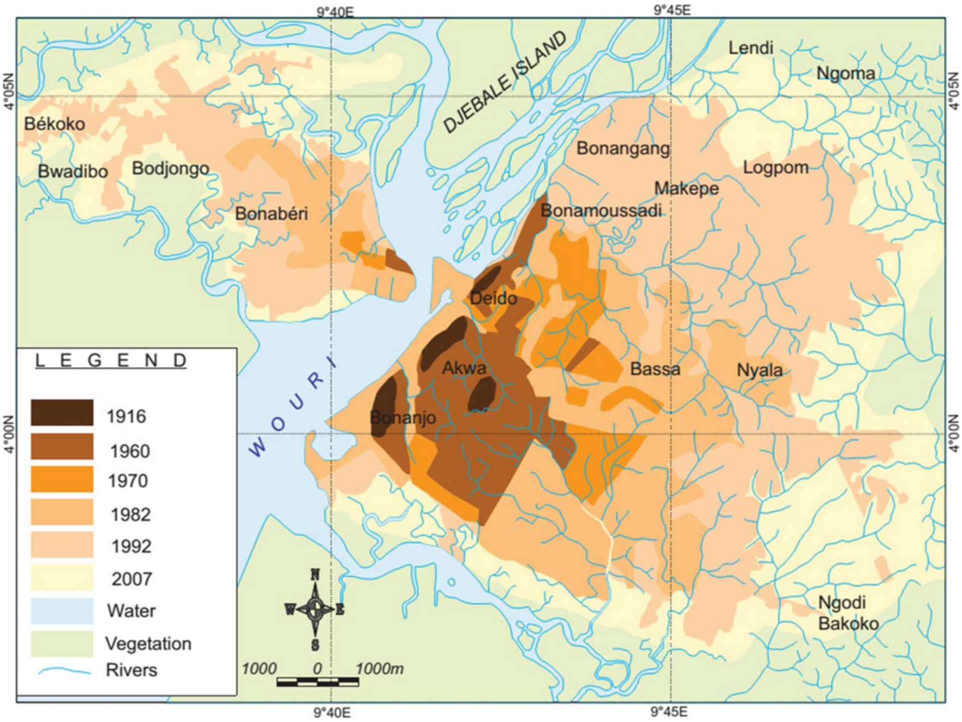

Figure 10. Changes in the extent of inhabited areas in Douala: 1916 to present.

commercial), Bali, Deido (residential area of indigenous Douala populations), sections of Bonaberi and Basa (indigenous villages, administrative center and railway station). These initial settlements tend to have relatively lower risks of floods, and were sufficiently supplied with key socio-economic infrastructures such as roads, drinking water, health care, electricity and schools. The second phase of occupation which began in the 1980s was characterized by a rapid expansion of the city limits into the remaining vacant lands which, for the most part, were unsuitable for construction and habitation. These new areas are characterized by the unstable nature of their loose silt soils, low elevations which make them prone to floods, and for many, the proximity to the sea which, besides floods, makes them vulnerable to inter-tidal surges of seawater (Figure 4). The settlements are generally informal (without cadastral and building plans). Areas occupied during this second phase include low-lying areas of Nkolmintag, Babylon and Ngangue, as well as areas south-east the international airport, north-east of the Bassa industrial zone and the Bonaberi West. These are areas that suffer the most damage from annual floods (Figure 4).

6.2.2. Low rate of development of drainage infrastructure

The rate of increase in demography has not been matched by the rate of infrastructure development in Douala. Currently, earth roads and footpaths make up most of the road infrastructure of the Littoral Region (Table 5). The limited ability to provide and sufficiently manage drainage infrastructure on such roads is well known, especially in the context of financial constraints faced by municipal authorities in urban councils of the

Table 5. Distribution of households (in percent) according to the means of access to homes in the Littoral Region.

Type of access to homes	Percent households
Tarred roads	12.9
Earth roads	54.5
Footpaths	30.4
Trails	1.8
Others	0.4
Total	100

developing world. The Douala City Council cites problems of limited funds as one of the key constraints for the mismatch between rapid spatial urban extension and necessary socio-economic services to cope with the growing demography.

Within the context of flood risk, the poorly planned expansion has choked natural waterways and drainage systems on which the city depended for the rapid transfer of rainstorm waters to the sea. Besides the anarchic expansion of the city and occupation of natural drainage systems, the rapid population growth also translates to a massive increase in the production of household and industrial wastes. The poor capacity of city council infrastructure and systems to deal with the large volumes of urban wastes has been well documented. The open disposal of wastes on garbage fields located on seasonal drainage channels is a common sight outside the city center. While the expectation is that these wastes will eventually be transported out of the dumpsites by the streams (which swell in the rainy seasons), these wastes end up forming barriers to the free flow of stormwaters and contribute to the generation of floods (Table 6).

In a survey of poverty and urban mobility in Douala (World Bank 2004), city dwellers persistently cited impediments that have to do with the poor state of roads (untarred roads) and the accumulation of wastes on sidewalks and key issues of mobility (Table 6). There appeared to be no substantial differences between poor and non-poor residents of the city on the problems associated with urban mobility. All of the factors cited have a strong association to the causing of floods in the flat urban lands.

Table 6. Percentage of poor and non-poor city dwellers citing various types of impediments to walking based on frequency of mention (source: World Bank 2004).

Impediments	Poor	Non-poor
Obstruction of sidewalks	45	43
Poor condition of roads	43	51
Bad smells, garbage, filth	41	32
Lack of lighting at night	35	41
Lack of sidewalks or sidewalks in poor repair	32	35
Risk of road accidents	28	20
Risk of assault	24	29
Poor condition of drainage systems	15	16

7. Discussion

This study set out to examine the claim that changes in characteristics of rainfall are responsible for the recurrent floods in Douala, Cameroon, and to assess the contribution of other factors in explaining the recurrence of more intense and devastating floods in this city.

The finding of this study is that there is no evidence in the rainfall record (alleged to be a result of climate change) that can directly be blamed on the recurrent floods in the city of Douala. This is evidenced from the trends of total annual rainfall anomalies (Figure 5), monthly rainfall and number of rain days (Table 3), and the frequency of high intensity rainfall events (Figure 7). The causes of these floods in Douala, Cameroon, can instead be attributed to the rapid and poorly planned occupation and transformation of the city's landscape (Figure 10). Land-use planning and governance failures therefore seem to be the greater culprit than climate change, as evidenced in the rainfall data-set. The outcome of this study corroborates other studies which have identified land governance as an important trigger of urban morphology (Barau *et al*. 2015). Barau *et al*. (2015) found evidence that the current rate and extent of urban morphology in Kano, Nigeria, could be attributed to governance failures. The case of Douala reported in this study, and that of Kano (Barau *et al*. 2015) are cases that are triggered by governance failures, and have the potential to exacerbate vulnerability of this landscape and its inhabitants to global environmental changes. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change states that: "the largest mitigation opportunities with respect to human settlements are in rapidly urbanizing areas where urban form and infrastructure are not locked in, but where there are often limited governance, technical, financial, and institutional capacities" (IPCC 2014b, 27). In the same vein, the IPCC (2014a) report recognizes that the design of climate policy is influenced by the perception of risks and uncertainties by individuals and organizations. It therefore follows that making use of mitigation opportunities must begin by properly identifying and recognizing the sources of problems and risks.

While our analysis does not show that climate change-induced variations in rainfall patterns are the direct cause of recurrent floods in Douala, it does not mean that climate change does not contribute to, or have the potential of contributing to, floods in the city. Cameroon has a coastal length of 548 km along the Atlantic Ocean (Brown, Kebede, and Nicholls 2011). There is currently strong scientific consensus on the role climate change is already playing in raising sea levels worldwide with potential to contribute to flooding in many coastal areas (Hallegatte *et al*. 2013; Hanson *et al*. 2011; IPCC 2007; Nicholls *et al*. 2011; Vafeidis *et al*. 2008). There is an increasing trend of global mean sea level change (1900−2010) relative to 1986−2005 (IPCC 2014a). Coastal regions (especially areas with significant extents of low-lying flat surfaces such as Douala) stand to be vulnerable to such rises in sea level. The IPCC also notes that the "rates of sea level rise over broad regions can be several times larger or smaller than the global mean sea level rise for periods of several decades, due to fluctuations in ocean circulation" (IPCC 2014a, 42). The consequences and costs of such changes in sea level on human health and socio-economic development are expected to be substantial (Chalabi and Kovats 2014; Scrieciu and Chalabi 2014). Using the Dynamic Interactive Vulnerability Assessment model, a study by Brown, Kebede, and Nicholls (2011) ranked countries by the relative impacts and costs of natural disasters up to 2100. The goal of this initiative was to provide greater insights into national level vulnerabilities to natural disasters. The study found that, in absolute terms, several countries regularly made up the list of the top 10 rankings of high relative impacts and costs of natural disasters. With regards to flooding and the forced migration resulting from sea level rise, these people-based impacts identified Mozambique, Cameroon, Tanzania, Morocco and Egypt as the most vulnerable. The study estimates that about 78,000 people and 5.4 billion dollars' worth of economic assets will be vulnerable to exposure under the future socio-economic situation and the 2070s climate change scenario in the city of Douala alone (Brown, Kebede, and Nicholls 2011). Nonetheless, robust and systematic studies that assess the contribution of sea level rise to the current incidences of floods in the city of Douala remain scarce.

The first step in reducing flood risks in large cities is that of recognizing the risk (Tiepolo 2014). Recognition of the risks of flooding can only be adequate if the causes, extent, frequency and other features which define the character of urban floods are well defined and understood. To properly define and implement successful mitigation, coping and adaptation strategies, it is imperative that an understanding of the causes and risks of floods are not limited to decision-makers and scientists only. In the case of floods in Douala, associating floods with divine intervention or changes in rainfall patterns caused by global climate change tends to give the impression that city populations can do nothing about it. It also absolves city councils and other urban planners of their shortcomings in planning, as well as foresight on challenges to designing appropriate systems to deal with future disasters that may befall the city. This is not conducive for the mitigation of risks associated with such floods, the development of adaptation strategies by residents and city dwellers, as well as the development of strategic long-term goals for achieving resilience by city administrators.

A number of drainage management measures are increasingly being used to make communities more flood-resilient. These include flood-proofing, land-use planning, relocation of people living in risk zones, adoption and enforcement of appropriate building codes, among others. The use of bioswales has gained substantial attention as a method of increasing the flood resilience of communities in recent years (Pataki *et al.* 2011; Steiner 2014). Bioswales are stormwater runoff transportation systems that provide an alternative to storm drains. They are generally urban landforms designed to absorb flows or carry runoff from heavy rains to storm sewer inlets or directly to surface waters (Di Giulio and Kinabalu 2011). The Douala Urban Council has put in place, and is encouraging structural measures of flood control. This is by means of building culverts and drainage systems to help convey water out of the city. These measures have hardly kept pace with the geographical expansion of the city. Vegetative landscapes such as bioswales can contribute to current efforts of flood mitigation by reducing the amount of urban stormwater runoff and the flood incidences associated with such flows. Bioswales also have a number of benefits that can contribute to improving the quality of urban living for a city such as Douala. These include: reducing the load of pollutants in urban surface waters; increasing soil and groundwater infiltration; increasing the amount of urban green spaces which can improve air quality, as well as contribute to lower urban air temperatures. The key advantage of considering bioswales as an approach to urban flood resilience is because such systems can more easily be retrofitted in most landscape modification processes. More so, construction and maintenance costs of bioswales are often lower than those of conventional stormwater management systems – an important consideration for city councils with limited financial resources.

8. Conclusion

With expectations of increases in the number of cities and urban populations in many parts of the world within the next half century, concern over the causes of major environmental disasters affecting urban areas is a legitimate one. While the body of knowledge that links global environmental changes such as climate change and its associated outcomes to environmental risks of urban areas is substantial and growing, there is a need to clearly understand the specific situation of individual urban areas. Distilling such granularities is an essential step in identifying the precise causes of disasters and the vulnerability of specific urban environments to them.

Drawing from a study of rainfall records of Douala from 1951 to 2008, we find no direct attribution of changes in the amount of rainfall or other rainfall characteristics that should explain the increase in the occurrence of floods in this urban area. Precisely, a significant negative annual anomaly of total is identified. This negative anomaly is further confirmed by a significant negative shift in mean rainfall observed since the early 1970s. No significant trend is found in the frequency of extreme daily rainfall occurrences in Douala. Also, the number of days of rainfall does not show any increase. Instead, the site (coastal location) and situation (flatness of the terrain) of Douala are seen to favor the occurrence of flooding, especially when the local hydrography is imprudently altered. The demographic and socio-economic history of Douala gives insights and associations to the situations of floods in the city. The process of urbanization that includes (among other things) the construction and concentration of buildings, roads and other impervious surfaces has direct effects on its surface hydrology of urban areas. This is because the process of urbanization generally involves (at least in the case of Cameroon) large-scale deforestation of formerly rural areas. The role of vegetation in stabilizing catchment hydrological processes is well known. The changes resulting from deforestation and the replacement of vegetated areas with impervious urban surfaces negatively affect the capacity of urban areas to effectively infiltrate, store and convey water during and after rainstorms. As a result, increasingly, even modest rainfalls in the Douala metropolitan area have the potential of generating floods.

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Disclosure statement

The authors declare no conflict of interest.

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Appendix 1

Table 1.1. Major floods reported in Douala (1990–2014).

Year, month	District(s)	Human toll	Other impacts
1990, July	DOUALA II (Nkolmitag & PIC 5)	No deaths, several made homeless	Destruction of homes and property (furniture, documents, appliances, clothing), pollution of wells. Blocking traffic and disruption to traffic, transport and slowing economic activity, spreading garbage.
1993, August	DOUALA II & III (Tergal, kolmitag, Brazzaville, New Bell, Dibom, Soboum, Bilongué, Madagascar)	No deaths	Material damage to homes, pollution of wells. Spreading garbage in the home, blocking crossings, disruption of lifestyle.
1996, June–July	DOUALA II, III, IV & V (Tergal, Nkolmitag, Brazzaville, New Bell, Dibom, Soboum, Bilongué, Madagascar, Makepe Missoke, Bepanda, dogbati, Béssèkè, Mabanda)	No deaths, few serious injuries	Damage to homes and destruction of equipment water and electricity, pollution of wells. Spreading garbage, mud and silt on the road, slowing transport, movement of goods and people and economic activities, lack of water and electricity for a few days, disruption of lifestyle.
1998, August	DOUALA II, III & V	No deaths	Material damage to homes, pollution of wells, contaminated water. Spreading sludge and garbage pollution.
2000, August	DOUALA I, II, III, IV & V	2 dead Nkolmitag & Ndogpassi, several injuries, homelessness, psychological trauma	Property damage to businesses, hospitals, schools, markets (Mboppi, Sandaga), the administrative offices, homes, destroyed two bridges and roads. Blocking traffic and disruption of traffic, slowing transport and temporary halt of economic activities, destruction of goods and products, spreading of waste and wastewater for more than 3 days, disruption of lifestyle.
2002, August	DOUALA II, III, IV & V	No deaths	Material damage to homes, pollution of wells. Spreading garbage, slow transportation and economic activities, disruption of lifestyle.

(continued)

Year, month	District(s)	Human toll	Other impacts
2009, June to July	DOUALA I, II, III, IV & V	No deaths, few serious injuries	Destruction of homes and property, pollution of wells. Slowdown in economic activity, transport of goods and people, disruption of lifestyle.
2009, September	DOUALA I & V (Akwa, Bonapriso, Bonanjo, Bali, Cité des Palmiers)	1 child drowning, and several serious injuries	Major shopping and office space damage, destruction of homes. Slowdown in economic activity, transport of goods and people, disruption of lifestyle.
2013, October	DOUALA I & V (Akwa, Bonapriso, Bonanjo, Bali)	No deaths, several serious injuries reported	Shutdown of roads, flooding streets, destruction of residential structures
2014, July	DOUALA I, II, III, IV & V	No deaths, several serious injuries, several made homeless	Material damage to homes, pollution of wells. Spreading garbage, slow transportation and economic activities, disruption of lifestyle.