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RAINFALL VARIABILITY AND FLOODS OCCURRENCE IN THE CITY OF BAMENDA (NORTHWEST OF CAMEROON)

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Key words: Bamenda, climate change, flooding, risk, vulnerability

Abstract. This study is based on analysis of rainfall data from 1951-2010 collected at the climatic station of Bamenda. We also use the results of a questionnaire survey applied to 172 households in at-risk neighborhoods. The inventory of some cases of flooding that occurred in the city of Bamenda was done through focus groups. The appreciation of the socio-economic and demographic environment is based on surveys among Cameroonian Households by the National Institute of Statistics (NIS) and General Census of Population and Housing. Statistical examination revealed that annual rainfall in the city of Bamenda experienced a break in 1958. This break buckled the wettest decade of the series. After three decades of worsening, rainfall is experiencing rising since early 1990. The average profile of the annual distribution of rainfall shows a concentration of over 53% in 03 months (July, August and September). During these three months, the rivers of the city know their flood flows and populations in the valleys are affected. The analysis of the annual number of rainy days shows a downward trend and an increase of extreme rainfall event frequency (≥50mm in 24h). It is also apparent that more and more years are experiencing erratic distribution of their precipitation. Then, the perception of people is significantly reduced. Subsistence activities are also affected and development is facing new subtleties. In conclusion, the rainfall experienced strong variability in the city of Bamenda. This situation reinforces the risk of flooding by increasing flood water and increasing the vulnerability of populations.

Introduction

The issue of climate change has gradually inserted in the scientific literature with successive IPCC reports (1990, 1995, 2001, 2007 and 2014) and studies conducted by other institutions and governments. Deregulation in the climate

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system is shown by the increase in the average temperature of the earth, the gradual rise in sea level, increased episodes of extreme rainfall. These events are felt in different ways by countries. In Cameroon, the United Nations Development Program (UNDP) in a study conducted in 2008 highlighted the following trends: decrease of average annual rainfall (-2.2% per decade since 1960) increase of annual average temperature (0.7 ° C from 1960 to 2007) and the rise in sea level of 1.8 to 2.2 mm per year between 1948 and 2003 (Fonteh et al. 2009). In general, drought, desertification, wildfires, storms, floods are among other climate risks increasingly strengthened. Flood risk throne in the front row and presents the annual occurrence record. In addition it affects all inhabited agro ecological zones of the planet (Guha-Sapir et al. 2014). Human settlements with high densities are the most vulnerable. In Africa, Nouaceur et al. 2013 highlighted an increased flooding in some major cities in Mauritania and Burkina Faso.

In Cameroon there is an increase in the frequency of flooding in all agro-ecological zones (MINEPDED 2015). Bamenda located in the western highlands of Cameroon presents a peculiar situation. With Abundant rainfall (> 2300mm / year), very hilly relief, poor environmental conditions and very limited control of urban development, this city is very exposed to flooding. Furthermore the ambiguity of the land tenure system, urban poverty, poor civil protection, high population growth and uncontrolled spatial expansion of the city explain the high vulnerability of populations (Sunday and Ndi 2012). This study has two complementary objectives:

- Firstly, to present the rainfall trend in the city of Bamenda. We used heights and monthly numbers of rainy days to describe year to year evolution and seasonal tendencies. Statistical tools help to highlight breaks and ongoing changes in the data series. The period chosen for this study is from 1951-2010.

- Secondly, the impact of the rainfall changes on the risk of flooding will be assessed. The premise of this objective is based on observations city dwellers complaining of more frequent flooding affecting increasingly large areas. Further socio-demographic and economic data used to assess the vulnerability or better sensitivity to risk populations.

1. Methodological approach

1.1. General presentation of the city of Bamenda. Bamenda is the head quarter of the Mezam division in the Northwest Cameroon region. It is made of three subdivisions (Bamenda 1, 2 and 3) with 391 km² as total area. This study concerns the urbanised part known as the city of Bamenda; that is about 12.49% of this surface (4 880 hectares). The figure 1 shows the location of the city of Bamenda, between 5°56-6°00N and 10°08-10°12E. The population was about 496 931 inhabitants in 2012 with 4.9% as annual growth rate. The city of Bamenda takes place at the heart of the western highlands of Cameroon. Its relief consists of interspersed plateaus with deep valleys. There are two topographic units separated by a scarp oriented NE – SW (Neba 2011). Above the cliff, stands the upper plateau. It represents 10% of the total area of the city. Altitudes here vary between 1472m and 1573m. The minimum altitude of the lower plateau is 1201m. This part of town is home to nearly 90 % of urban facilities. The Mezam Division is part of the Niger catchment; fueled in Cameroonian south part by the Mentchum River. One of its tributary is the Mezam River that drains all runoff from the city of Bamenda.

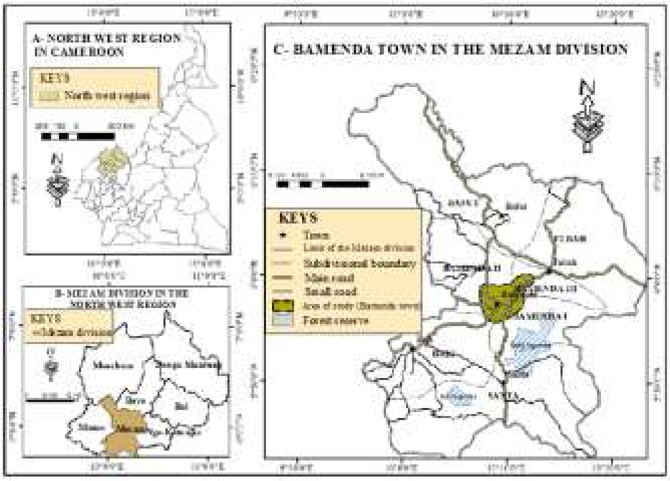

Figure 1: Location map of the area of study

1.1. Data collection. After a literature review, field work was done in three stages. First the design and implementation of a questionnaire to 172 target households in the most exposed neighbourhoods and sensitive to flood (Sisia, Mulang, Abangoh, New Layout, and Mougheb Foncha Below). The questionnaire was used to collect information on the hazard from the population of the city; their perceptions and acceptance. In addition, the questionnaire helps to assess the opinions of people on the various adaptation strategies developed by both city dwellers and local authorities. Semi-structured surveys organized in the target neighbourhoods' assembly points of view to reconstruct the history of flood in the city of Bamenda. Monthly rainfall and number of rainy days (1951-2010) was harvested in the regional delegation of the Ministry of Transport for the Northwest. Administrative boundaries were drawn from the forestry atlas of Cameroon edits by the National Institute of Cartography (NIC). An ASTGTM image downloaded from https://lpdaac.usgs.gov/ was use to design topography and hydrology features.

1.2. Analysis and interpretation

The data analysis was done separately. A data capture mask on SPSS enabled to analyse the answers to the questionnaires. The same application was used in the construction of tables and figures. For rainfall data, many operations were carried out:

- The Hubert segmentation; it allows to observe the nature of changes in the series of data (Hubert et al. 1989) .With a significance level of the Scheffe test: 1%, a major break occurred at the end of the 1950s . This test was run through KhronoStat program developed by IRD.

- The Standardized Precipitation Index (SPI), this statistic helps to differentiate dry years and wet years.

$$\mathrm{SPI} = \frac{x-\bar{x}}{\sigma}$$

x= annual rainfall, $\bar{x} = \text{mean}$ and σ = standard deviation.

- The calculation of the coefficient of variation (CV); It is the ratio of standard deviation to the mean. It is expressed in %. This index is useful in assessing the relative variability of a distribution.

$$cv = \frac{\sigma}{\bar{x}} \times 100$$

- The correlation coefficient (r); it allows the identification of a correlation between two quantitative variables. His equation is.

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

In this equation, "x" is the series of rainfall between 1995 and 2012 and "y" the series of numbers of victims (the dead) over the same period.

The mapping of flood risk in the city of Bamenda results from the application of the hydro geomorphology method (Ballais et al. 2011) by the superposition of several layers of information including topography, hydrography and land use (Google Earth). The area marked in red (see fig.7) is characterised by very gradual slopes (between 0 and 2) and drained by a river with regular runoff. The amber area is part of the major bed of rivers with slopes less than 4°. The green area presents average slope that allows rapid circulation of surface water. The red area corresponds with spaces that cannot be built such as prescribed by the Town

Planning Code of 2004 (Act No. 2004/003). The amber area is subject to special arrangements and any construction must be regulated.

2. Findings

2.1. General trends of rainfall: up between random variations and changes. The data set (1951-2010) gives an overview of the rainfall behaviour in the city of Bamenda. Overall, the interannual average rainfall is 2354 mm. This is a relatively high (Tsalefac, 1983). The orography plays an important role in this situation (Figure 2).

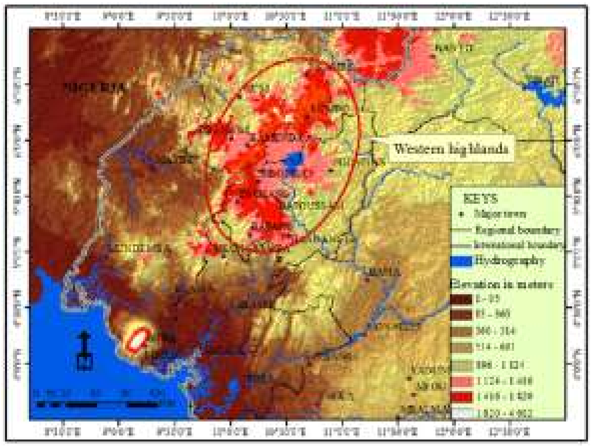

Figure 2: Location of the city of Bamenda in the high western lands of Cameroon (Source: Image ASTERDEM and Interactive Forest Atlas of Cameroon 2011)

Part of the fault line of Cameroon, high Western land is located at altitudes between 1,000 and 2,000 meters. Situated at 250 km from the coast, the city of Bamenda is located on the wind side of this highland. It experiences each year the arrival of a humid wind (monsoon) which in its ascent causes enormous amounts of precipitation.

Locally, there are three large lakes in the area (Bamendjing, Nyos and Awing) whose evaporation contributes to rainfall in the area. In addition, the presence of several forest reserves (Ngemba Bafut, Bafi Ngemba, Nkom Wum, Mbembe and Fungom) plays an important role in evapotranspiration and clouds formation. The analysis of the series (1951-2010) allows highlighting a strong interannual variability around the mean (Figure 3).

Between 1951 and 2010, there are 31 deficit years. With years of extreme drought as in 1964, 1973 and 2003 ... Counted among the driest years since 1871 (IPCC 2007) 2003 experienced a shortage of more than 19% of its rainfall in the city of Bamenda. There are 29 surplus years, including 02 years of extreme humidity (1954 and 1957) and 07 years of high humidity (2> SPI> 1). In general, there is a concentration of exceeds in the early years of the series and severe droughts in 1990 and 2000; hence the general downward trend of precipitation. Hubert segmentation defines two distinct portions with different trends in this data series with a shift in 1958. This break has a probability density of the order of 0.31 as shown in Figure 4.

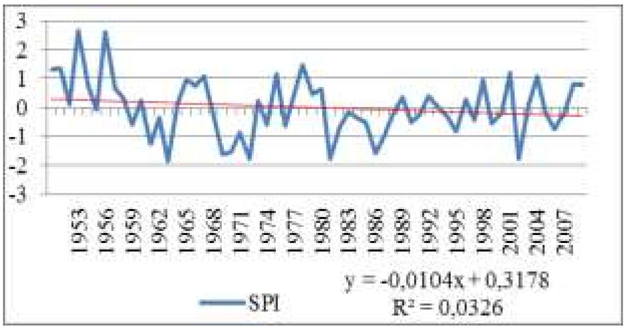

Figure 3: Standardized Rainfall Index

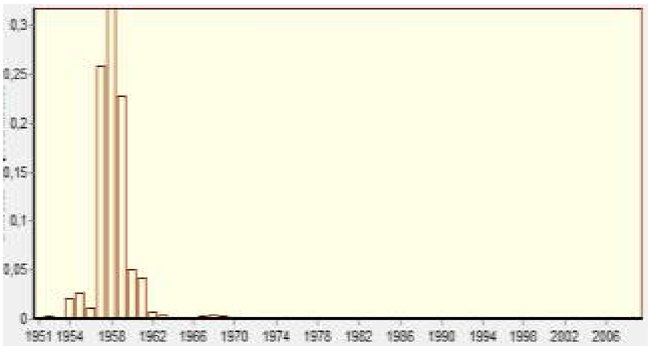

Figure 4: Probability Graph procedure from Lee and Heghinian

Prior to 1958, a constant high rainfall is observed with an average of 2649 mm. After the break, the variability is more pronounced with an average rate of variation of 11.40%. Furthermore, the tendency is upward of precipitation is felt since the early 1990s Table 1 shows the characteristics of the six decades that make up this statistic series.

The tendency to higher amounts of rainfall for the last two decades and especially the strong interannual variations may be related to the increase in Sea Surface Temperatures (SST) in the Atlantic Ocean (Camberlin 2007). In addition, the consumption of fuels, forestry and agriculture activities are causing greenhouse gas emissions (CO2, CH4 and NO3) that contribute to climate variability at the global scale.

Table 1: presentation of the rainfall decades from 1951 to 2010 series

Decade	Mean	Standard deviationα	variation index (cv) en %
1951-1960	2582,67	270,483629	9,54834129
1961-1970	2299,56	263,630955	8,72264791
1971-1980	2315,21	269,975034	8,57564483
1981-1990	2225,57	189,857508	11,7223175
1991-2000	2325,58	132,887863	17,5003191
2001-2010	2378,37	228,341625	10,4158407

2.2. Impact of the rainfall variability on the hazard. A Flood as a risk is the product of a hazard and a vulnerability. The flood that is to say, the upwelling in the valleys is being strengthened and vulnerability understood as sensitivity and exposure is increasing because of the forcing of climate and hydrological world systems.

2.2.1. Increasing the height of flood water. The gradual increase in annual rainfall amounts especially on the last two decades is the cause of increased flood water heights. The surplus rainfall enhances the speed of water runoff power and duration of submersion. The area is also facing constancy or even a slight decrease in the number of rainy days (fig.5).

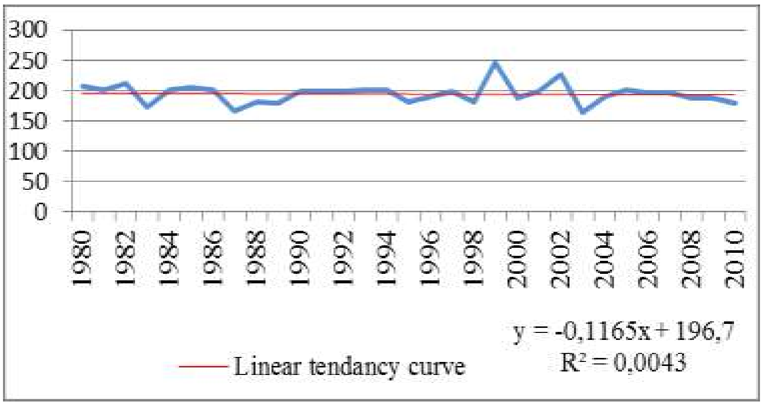

Figure 5: Structure of the annual number of days of rainfall in the Bamenda city (1980-2010)

It rains on average 194 days each year in the city of Bamenda (53% of the year). This situation is typical of equatorial and humid tropical climates (Suchel 1987). Over the past two decades, increasing quantity of precipitation was not the result of an increase in the number of rainy days. Thus there is a higher frequency of extreme rainfall (≥50 mm in 24 hours). People testify more frequent and severe flooding in quarters of the city of Bamenda (Table 2).

Table 2: Perception of the floods by the population

Current state of flooding	Number of favourable responses	Percent
Less frequent and less violent	20	13.33
Stable	30	20%
More frequent and more violent	100	66.66%
Total	150	100%

Source: Field Survey

It shows that over 66% of families surveyed denounce not only increasingly frequent flooding but above all more and more violent. Violence refers to the power of destruction. It is true that for this situation, population bring up nearly 10% the wrath of the gods of the earth and witchcraft; but climate variability appears to have a significant share of responsibility alongside the urbanization poorly mastered (Nyambod 2010). Several situations observed on the field or related by some respondents illustrate the increase of the height of flood waters: the abandoned homes, swamped bridges (Plate1).

Plate 1: Examples of flooding (A = Mulang has abandoned house, B = bridge Ntamulung incorrectly calibrated).

2.2.2. Enlargement of flood areas. Bamenda takes place at the heart of the western highlands of Cameroon. Its relief consists of plateau interspersed by deep valleys. This relief is divided into two sets by a cliff oriented NE - SW over a distance of 6 km. Above the cliff, stands the upper plateau. The low plateau is at the bottom. The topographic profile A-B (figure 6) summarizes the relief of the city of Bamenda into two main shapes: Steep slopes and valleys. The steepest slopes of the escarpment are those located in the southeast of the city. The consequence of these steep slopes is their great capacity to collect water directly drained into valleys, where floods occur after heavy rainfalls. In addition, the bottom plateau has a few small peaks whose slopes are also involved in the rapid collection of surface runoff. There are two types of valleys including the "V" and "U" shapes. “U” shape valleys are prone flood areas.

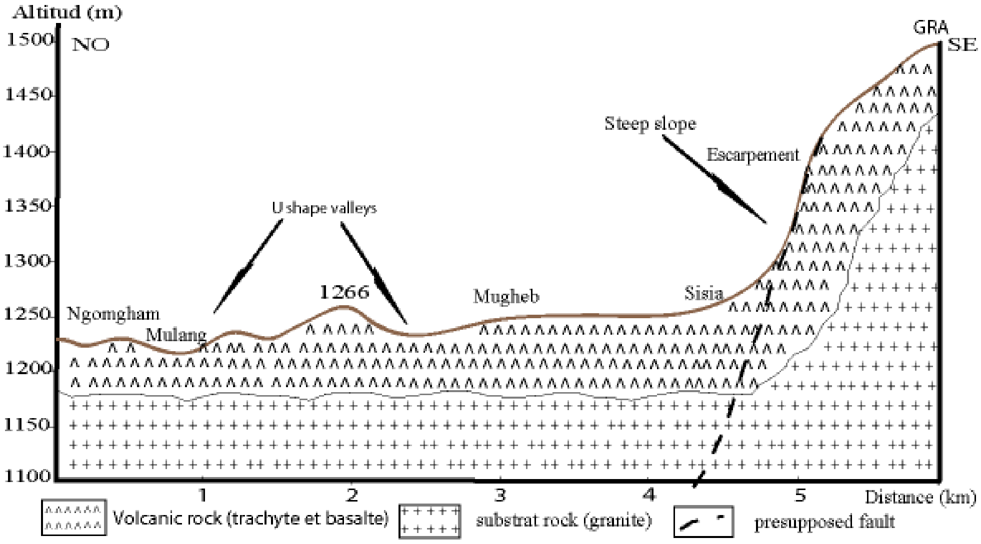

Figure 6: Bamenda topographical and geological cross section

Between 1980 and 1990, the city of Bamenda experienced its greatest spatial expansion and densification (Nyambod 2011 and Saha 2013). This period corresponds to the driest decade as shown in the table 1 above. Thus some areas of stream beds were built because of the temporary dryness. The recovery in rainfall causes flooding in these areas after each significant rain (Old town, Mulang and Below Foncha). The hydro geomorphological method (Ballais et al. 2011) by combining the topographical and hydrological factors allows the discrimination in the city of Bamenda of three types of flood risk areas depending on the level of exposure to the hazard; as presented in the Figure 7 below.

Roughly, the flood risk is prior to 30% of the city of Bamenda, with 10% higher exposure and 20% of average exposure. The risk area shows a widening and episodes of extreme rains are causing flooding in low exposure areas. The damages caused by these types of floods are multiplied tenfold because of the element of surprise.

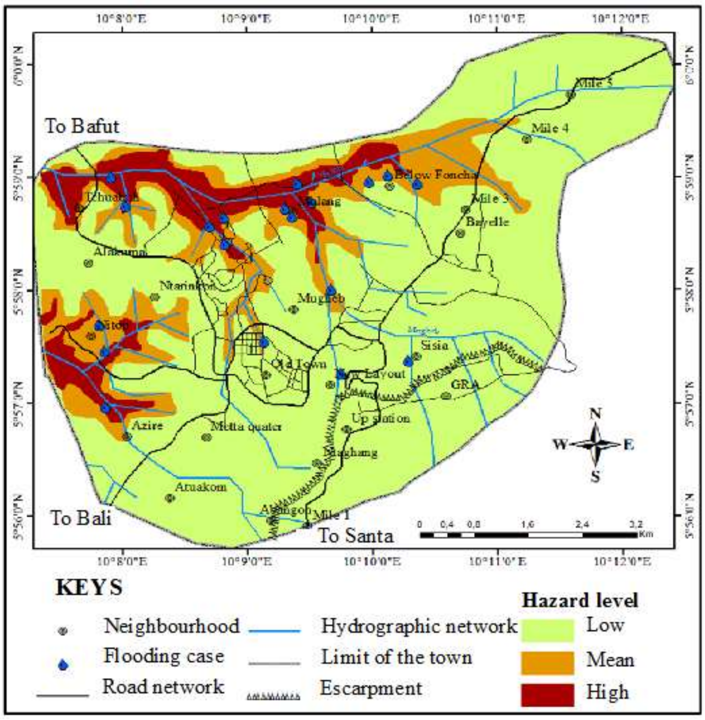

Figure 7: Flooding zoning in the Bamenda town (Credits: ASTER DEM Image, Interactive Forestry Atlas of Cameroon in 2011, Google Earth and field survey 2013)

2.2.3. Increased episodes of flash floods. Climate variability is also reflected in the instability of seasons. While it was hitherto possible to predict periods of heavy rainfalls, today it is more complex to master the behaviour of different climatic parameters. Analysis of monthly average data shown that the period from July to August is at the heart of the rainy season; but it is not uncommon to witness episodes of extreme rainfalls out of this period. The distribution of rainfall of the year 1999 illustrates this situation (Fig. 8).

The year 2009 was a tri-modal system with peaks in March, June and October. This may be the cause of flooding outside the known period. This year was hit by catastrophic flooding in Mulang neighbourhood where 01 death was registered without forgetting important material damages deplored in New layout and Bayelle. The year 2000 was also a special system with extremely abundant rainfall during the months of August and September that totalized more than 1000 mm of precipitation. The result was more deadly; 03 deaths recorded. Table 3 provides a summary of flood risk sensitivity to rainfall parameters.

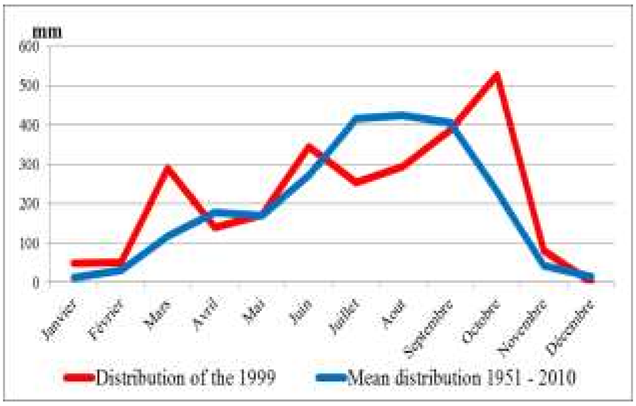

Figure 8: Rainfall of the year 1999 compared to the normal average 1951-2010 (Source: data from Regional Delegation of Transport of the Northwest)

Table 3: Summary of the sensitivity of floods to rainfall

Climate parameter	Sensitivity of the hazard facing rainfall parameters	Associated phenomena
Rainfall	Enlargement of flooding area	Invasion of more and more wide space by flooding water
		Accumulation of materials that obstruct ways of evacuation of water
	Increasing the height of the flood water	Overflowing in stream beds and flooding in the lowlands
		Increase of rainfall water in the cleaning up network and surface run off
		Overflowing of protection tools (dykes and vegetal shield
	Instability in the rainfall system	Upsurge of flash flood episodes
	Decrease of annual number of rainy days	Concentration of high rainfall period and upsurge of floods

Source: Saha, 2013

2.3. Consequences of rainfall variability on vulnerability

Understood as the ability to maintain in front of a hazard, the vulnerability of a given population is very sensitive to any phenomena that could impact not only the environment but also on the economic and social conditions of the population. Climate variability has three major impacts on people's vulnerability in the city of Bamenda namely the reduction of the perception and acceptance of risk, complexity in the development and management of risks by the authorities and the impoverishment of population already stricken by drastic economic conditions. Table 4 summarizes the impacts of rainfall variability on the vulnerability of population.

Table 4: Summary of vulnerability sensitivity to rainfall variations

Climatic parameter	**Vulnerability to rainfall variations**	**Associated Phenomena**
Rainfall	Impoverishment of the population	Endemic poverty Hunger
		Multiple attacks on the health of population More economic and human damage
	Decrease in risk perception	Reduction of the resilience of affected population Reduction of risk acceptance
	Complication of development planning	Weakening of existing infrastructures Increase in investment costs
	New requirements in risk management	Increasing costs for both proactive and operational management of risk

Source: Saha, 2013

2.3.1. Impoverishment of the most vulnerable population. Historically, the fight against poverty has always been a major concern for humanity. With the emergence of the concept of sustainable development, improvement of living conditions through the eradication of poverty is one of the pillars. In Johannesburg in 2002, during a World Summit on Sustainable Development (WSSD) all humankind reaffirmed its willingness to coordinate worldwide efforts to help the poorest people to better their conditions. This commitment had already been the subject of a General Assembly of the United Nations in 2000 when all nations of the world signed the "Millennium Declaration" in which "the desire to create a globally favourable climate for the development and the elimination of poverty" was contained in the Millennium Development Goals (MDGs).

Today the world is facing climate changes effects, which seriously hamper the efforts of states in the process of eradicating poverty. In some countries of the world such as Philippines, Nicaragua, Bangladesh, Benin, Ethiopia etc. climate change makes almost impossible the implementation of strategies against poverty. Some communities are also experiencing significant regression following the disasters they face. Note that the poorest populations of the world are the most vulnerable to climate change (IPCC 2014). This is due to their dependency *vis-a-vis* of nature and their very low ability to adapt because of their limited means. In Cameroon, 37.5% of the population lives below the poverty line (NIS 2014). This situation has remained steady since 2000. Today the government implements a policy to reduce unemployment by creating jobs in both the public and private sectors. These government efforts are threatened by the effects of climate change (MINEPAT 2009) affecting the country in several sectors. This is the case of agriculture, which is experiencing a decline in yields in the sahelian part. In 2012, the country faced several floods that annihilated the survival efforts of thousands of families in the Far North, North, East and Northwest regions.

In the city of Bamenda, as is it the case for other urban centres, poverty is endemic. The unemployment rate is increasing. The peri-urban agriculture is the main activity (MINHDU 2011). This activity is defined by IFAD as the most vulnerable activity to climate change especially when it is practiced in a rudimentary manner as in Cameroon. Thus, the instability of the seasons, and the decrease in the annual number of rainy days are factors that threaten agriculture in the city of Bamenda and its surroundings. In addition, damages caused by the floods are serious blows to survival efforts of urban population.

We can now count in the city of Bamenda homeless families due to upwelling in their neighbourhoods. It should also be noted that climate change will have an impact on people's health through the increase in attacks linked to diarrheal and infectious diseases.

2.3.2. Complication planning and risk management by the authorities. Arrangement of risky areas is complex. The different urban management structures of the city of Bamenda namely: the sub divisional councils and the Bamenda city council have very limited means and facilities. Thus, an upsurge of risk arises new challenges which requires new management as much human and material resources. For example it is now vital for every council to have a land use plan or local urbanization plan taking into account the variability of climate parameters. This implies new skills and especially funding further research on the current state and future of people's vulnerability to climate change. Questioned on the subject, the mayor of the Bamenda III council said that they have other more pressing priorities.

2.3.3. Decreased perception and low risk acceptance. Already quite limited, risk perception by the population of the city of Bamenda knows other hitches because of climate variability. Firstly, concerning the risky period of the year, the instability of seasons decreases the ability of the population to forecast and even the build their protections. Spatially, higher annual rainfall induces flooding in areas, where people are not prepared. These realities have been impacting on population adaptation efforts, especially the poorest unable to cope with new threats. The decrease in perception is also the origin of the reduction in risk acceptance especially when authorities and rescue services do not provide substantial helps. Table 5 summarizes all floods registered in the city of Bamenda since 1995.

Table 5: Some flood historical records in Bamenda (1995-2012)

years	Areas affected	deplored Damages
1995	Mulang, Small Mankon, Ndamukong ; BelowFoncha	– 2 deaths; – destruction of properties
1998	Old Town valley, Ntamulung, Mulang, Below Foncha.	– 3 deaths; – destruction of houses ; – destruction of farms
1999	New layout, Mulang, Below Foncha, Old Town valley, Bayelle.	– 1 death registered; – various other damages
2000	Mulang, Below Foncha	– 3 deaths; – various other damages
2001	Ntamulung	– 1 death
2004	Below Foncha, Musang.	– 1 death
2005	Musang, Mulang, Below Foncha, Ngomgham.	– 1 death – destruction of properties
2006	Mulang	– 2 deaths; – destruction of properties
2007	Ntaturu, Mougheb.	– 2 deaths; – various other damage
Août 2009	Below Foncha, Old Town valley, Bayelle.	– 2 deaths; – destruction of properties
Septembre 2009	Mulang, Ntamulung, Old Town, Sisia, New Layout.	– 2 deaths; – destruction of properties
Août 2010	Old slap	– 2 children seriously injured – several houses destroyed
2012	Mulang, Below Foncha	– destruction of family properties – 2 houses partially destroyed

Source: Nyambod (2010) and field surveys

Between 1995 and 2012, floods made about twenty victims in the city of Bamenda and material damage estimated at hundreds of millions of CFA francs. Most proven years were 1998, 2000 and 2009. In addition it should be noted that people generally avoid declaring their losses because they are aware of their illegal occupation of risk areas.

3. Discussions

Many authors and organizations have looked at climate changes in Africa. A split is emerging between observations made in the Sahelian tropical part and Equatorial Africa (AGRHIMET 2011); most pronounced disturbances affecting the dry Sahelian region. In Equatorial Africa, rainfalls show a consistency in the interannual distribution. Variations are attenuated and poorly organized in space. This is due to a poor response of Central Africa to interannual variability modes including ENSO signal (Bigot et al. 1998 and Hulme 1992). The response to SST is also much minimised compared to West Africa. This quasi independence of Central Africa to global changes can be explained by the presence of the thick canopy that maintains high humidity in the lower layers of the atmosphere. In addition, the situation in the heart of the continent on both sides of the equator decreases the sensitivity to modulations of the atmospheric circulation on a large scale (Camberlin 2007). Interannual changes of rainfall in the city of Bamenda are no exception to this general trend. The break occurred in 1958 confirms the independence of central equatorial Africa from the Sahelian zone where it is at the beginning of 1970s that a break occurred in the data of nearly 600 climate stations analysed by the AGRHYMET Regional Centre in 2011 . The random alternation of surplus years and dry years is a general trend noticed throughout Africa for nearly two decades (Lebel and Abdou 2009 and AGRHYMET 2011).

There is no doubt that climate risks in recent years have experienced significant strengthening. The frequency of droughts, storms and flooding increasingly reinforced in the world is raised by the IPCC as evidence of climate changes. Many West African countries have experienced in the beginning of 2010s the most catastrophic floods in their history (Badjana et al. 2014). The high interannual variability of rainfall and erratic seasonal distribution noticed in many central and West Africa increases the frequency of flash floods and extreme events (Mahe 2006 and Nouaceur et al. 2013). Although the correlation coefficient between rainfall and the annual number of flood victims in Bamenda is negative (-0.0036) the fact remains that climate variability affects both the hazard and the vulnerability of people exposed. A broader approach integrating material damage and all victims (the dead and people affected) is required to establish a complete correlation. A sectorial assessment of climate change effects presents livelihoods of the poorest populations of the world as very sensitive (IPCC 2007). In Cameroon, agriculture, rearing, fishing, public works, urban development, forestry are among other the most affected sectors (MINEPDED 2015). This is why city dwellers as the whole population become impoverished and city authorities are unable to answer their duties. It is absolutely necessary to pay more attention to climate changes is Cameroon because direct and indirect implications are too much and no economic, social or ecological sector is save.

Conclusions

The main objective of this work was to study the impact of rainfall variability on the risk of flooding in the city of Bamenda. From our analysis it is clear that the annual rainfall is increasing over the last two decades. The number of annual rainy day is going through a slight decrease. The distribution of rainfall over the year is also experiencing strong instabilities; increasing the unpredictability of the seasons. The consequence of these climatic changes can be noticed on the risk of flooding that is increasing in the city of Bamenda. At the level of hazard, there is an increase of flood waters and their turbidity, unstable seasons highlights the resurgence snap floods. The decrease in the number of rainy days is the reason of the increase of episodes of extreme rainfall. The vulnerability of populations to flooding is also affected. We notice: a decrease of population adaptability, weakening infrastructure, impoverishment of the population and the decrease in risk perception. This study invites human communities to reassess their exposure and susceptibility to natural hazards; taking into account not only stationary factors but also climate parameters marked in recent decades by important changes. The definition of risk areas in cities and the regulation on construction rules must consider climatic hazards increasingly strengthened.

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