Assessing Rainfall and Temperature Trend: implication on flood patterns in vulnerable Communities of Limbe and Douala, Cameroon

EMILIEN NAMONDO FINDI[1], MABEL NECHIA WANTIM[1], SAMUEL NDONWI AYONGHE[1]
Department of Environmental Science
University of Buea
P.O Box 63, Buea
CAMEROON
findiemilien@yahoo.com http://www.ubuea.cm

Abstract: - This study is concerned with the varying trends of temperature and rainfall within the cities of Limbe and Douala (Bonaberi municipality); all within Cameroon. These localities are characterised with significant changes in the pattern of the climatic variables, and has experienced fluctuations in rainfall and temperature reflecting declines. Therefore, the study aimed at evaluating trends and variability in rainfall and temperature, using timeseries analysis, Pearson's correlation analyses, Sen's slope and Mann Kendal tests in relation to flood trends within the study areas which previous studies didn't include. Seasonal and inter-annual data for a 31-year period (1985-2016) obtained from the meteorological stations within the various cities were used. Pearson's correlation analysis was used to express the correlation, Mann Kendall and Sen's statistics were used to test trends' existence to depict strength while assessing the anomalies. The results revealed occurrences of a rainy season (March to October), with most historical flood disastrous events, and a dry season (November to early March) which is often hot. Mann Kendall and Sen's slope findings showed positively ($p = < 0.05$) increasing trends over time for rainfall and for temperature. However, annual rainfall patterns in Limbe, showed no trend, since the computed p-value was larger (p-value=0.427) than the significant level (alpha = 0.05), with moderately positive temperatures. Decreasing trends in rainfall and increasing temperature was evident, Limbe has a higher rainfall average of 315.605mm compared to Douala with 272.549mm. On average the cooler years recorded the highest rainfall amounts and corresponding flooding events, while highest temperatures were between 27.32℃ for Douala and 26.19℃ for Limbe, with temperature increments and rainfall decrease being visible. This was attributed to climate change influence which has, during the past two decades, led to weather extremes manifested as destructive floods disasters in these cities. These findings could facilitate planning and management of water resources, being suitable in monitoring and predicting climate proceedings against floods, while contributing significantly to the sustainable management of rain- dependent activities within Douala and Limbe.

Key-Words: - Rainfall, Temperature, Pearson's correlation, Sen's slope Estimator, Mann Kendal analyses and Trend analyses, Limbe and Douala

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1 Introduction

Global climate change concerning water resources has recently affected vulnerable communities. The future increase in annual warming of the world [1] has brought about projected changes in temperature and rainfall, hydrological impacts, which have influenced potential evaporation, soil moisture and agricultural practices. Flooding, being a destructive type of disaster striking humans and their environment around the world, has in the last three decades caused over 2000 floods that have been recorded worldwide and has also affected the livelihoods of victims [2]. In total, about 56.1% of all disasters recorded by the Centre for the Epidemiology of Disasters (CRED) in 2010 were of flood origin, affecting close to 189 million people. Floods are estimated to have increased worldwide by 145.1 % in 2010 compared to the annual averages between 2000 and 2009 [3]. Such damages have negative effects on the livelihoods of victims, especially in developing countries like within the study sites where a majority of households still depend on smallholder agriculture for survival.

The influence of temperature on rainfall has been incorporated in an indirect, or sometimes a direct way in a number of studies [4]. High temperatures may result in exceedingly high rates of potential evaporation and low precipitation in areas dominated by an arid or semiarid landscape [5], leading to more evaporation and consequently increased condensation leading to high rainfall.

The importance of climate change on flooding has been analysed using the relationship between two primary climatic parameters: temperature and rainfall, with focus on changes that have resulted from natural and artificial causes. Rainfall is a key factor in shaping the vegetation, hydrology, water quality and quantity in the selected sites.

The study sites are similar to other flood vulnerable areas that have experienced increase in the frequency and severity of flooding incidents as a result of climate change, which is expected to worsen the already adverse flood risks [6], with more devastating effects on properties and inhabitants [7]. In Cameroon, according to data from the Centre for Research on the Epidemiology of Disasters' Emergency Events Database (EM-DAT), 4,200 people were affected by flooding in 1998 and 2006. In 2007, more than 10,000 people were affected in a single year and in 2008, 25,000 people similar to 2012 with nearly 52,000 persons affected. Weather and climate extreme events (e.g., floods) have the most severe and damaging impacts on the natural environment, human health and infrastructures [8]. Previous studies on floods carried out in these cities, focused primarily on the damages caused (e.g., loss of lives and properties), adaptation measures (to rainfed agricultural aspects) within the flooding events and their recovery stages [8], as well as retreat period for rain onset, without focusing on the climatic and risk surface changes over the years. This study therefore aimed to evaluate the trends and variability in rainfall and temperature, using timeseries analysis, Pearson's correlation analyses, Sen's slope and Mann Kendal tests in relation to flood trends within the study areas. Findings will add knowledge and available data through assessing the relationship between trends of parameters of climate change and patterns of flood events with the hope of using these trends to propose adaptation strategies which could be useful in decision making by the governing bodies within the Bonaberi and Limbe municipality.

2 Materials and methods

2.1 Description of Study Area

Cameroon is within latitudes 1°45´N to 13°´N and 475,442 km^2, with Yaoundé as the capital city. The study area Bonaberi Municipality (one of the localities in Douala city) lies between latitude 04°05´N and longitude 9°35´E). Limbe lies between latitude 3°90´ and 4°05´N; and longitude 9°29´and 9°13´E along the coastal area of the Southwest Region [9] (Figure 1) with volcanic rocks [10]. The average temperatures in Limbe range between 10°C, in the rainy season and 32°C or higher, in the dry season.

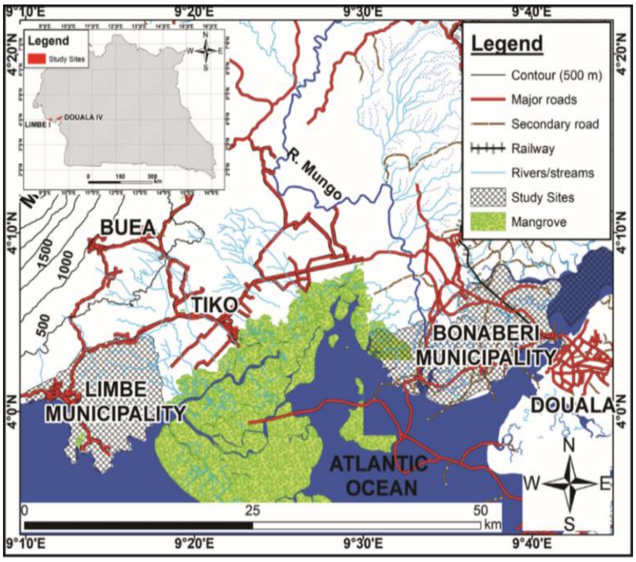

Fig. 1: Location map of the study sites in the Limbe and Douala.

2.2 Data acquisition and processing

Data for rainfall and temperature were collected from the meteorological stations within the various cities after receiving permits based on the study needs. For Limbe, it was recorded by the CDC while for Douala information was obtained from the meteorological Centre in Bonanjo, Douala. The study used seasonal and inter-annual data in plotting the varying trends. The data records used in this study are for a period of 31 years (1985-2016). The continuous records were split into sub-series to perform the time series comparisons tests, and the basic statistical properties (i.e., mean average, standard deviation). The seasonal and annual mean data of temperature and precipitation were computed using Matlab spreadsheet.

2.2.1 Mann-Kendall test

The Mann-Kendall test [11, 12] was used to establish whether there is a trend (increasing, decreasing or no trend) in the time series, with a confidence level of 95%, and the hypotheses given as:

H_0: there is no trend in rainfall/temperature time series;

H_A: there is a trend in rainfall/temperature time series

The methodology involved three main steps: 1) firstly, it detected the presence of increasing or decreasing rainfall and temperature trend using the nonparametric Mann-Kendall test; 2) it estimated the slope of linear trend with the nonparametric Sen's Slope estimator; and 3) lastly, regression models were developed and charts produced. The Mann-Kendall statistic S is given as:

$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} sgn(x_j-x_k)$ __________ (1)

Where S is Mann-Kendall statistic and are the annual values in years j and i, j>i respectively, and N is the number of data points. The value of is computed as follows:

$$\text{sgn}\,(x_j-x_k)=\begin{cases} +1, \; if\;(x_i-x_k) > 0 \\ 0, \; if\;(x_i-x_k) = 0 \\ -1, if\;(x_i-x_k) < 0 \end{cases} \quad \text{\_\_\_\_\_\_\_\_ (2)}$$

Where, and *sgn* is the signum function. The application of the trend test is done to a time series xi that is ranked from i = 1, 2 …. n-1 and xj, which is ranked from j = i+1, 2 ...n. If n < 10, then value of |S| is compared directly to the theoretical distribution of S derived by Mann and Kendall. The variance statistic is given as:

$$\text{Var(S)}=\frac{n(n-1)(2n+5)}{18} \quad \text{\_\_\_\_\_\_\_\_\_ (3)}$$

The presence of a statistically significant trend was evaluated using the Z value. A positive value of Z indicates an upward trend and its negative value a downward trend. The Z values were tested at 0.05 level of significance. The Z test statistics is given by:

$$Z=\{\frac{S-1}{\sqrt{Var(S)}},\; if\; S > 0\;\; 0,\; if\; S = 0\;\; \frac{S+1}{\sqrt{Var(S)}},\; if\; S < 0 \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (4)}$$

If Z>0, it indicates an increasing trend, and vice versa. Given a confidence level α (alpha), the sequential data experience statistically significant trend if |Z|>Z(1-α/2), where Z(1-α/2) is the corresponding value of P=α/2 following the standard normal distribution. In this study, 0.05 confidence levels were used.

The study verified if there were any existing trends in the rainfall and temperature data sets used from 1985 to 2016 seasonal and annual. The trend in the series was monotonous. The Mann Kendal test was calculated by ranking the observations. For two or more observations with same value, they were assigned the same rank. In the next step, a lower and higher value for each set were added to get two numbers. The difference between these two numbers constituted the test statistics for the Mann-Kendall test. Statistical conclusion is based on one standardized version of this test statistics, which is approximately normalized if we have more than 10 observations to exclude being auto-correlated

2.2.2 Sen's slope estimator test

Non-parametric method [13] was used to estimate the magnitude of trends in the data time series. The slope of "n" pairs of data can be first estimated by using the following equation:

$$Bi = \text{Median}\,\frac{[X_j-X_k]}{j-k}\;\forall\;(k<j) \quad \text{\_\_\_\_\_ (5)}$$

In this equation, X_j and X_k denote values data at time j and k, respectively, and time j is after time k (k ≤ j). The median of "n" values of β_{iis} the Sen's slope estimator test. A negative βi value represents a decreasing trend, a positive β_i value represents an increasing trend over time. If "n" is an even number, then the slope Sen's estimator is computed by using the following equation:

$$\beta_{med}=1/2(\beta[n2/] +\beta[(n+2)2/] \quad \text{\_\_\_\_\_\_\_ (6)}$$

If "n" is an odd number, then the estimated slope by using the Sen's method can be computed as follows: βmed=β[(n+1)2/] (7). Lastly, βmed is tested by a two tailed test at 100 (1−α) % confidence level, and the true slope of monotonic trend can be estimated by using a nonparametric test [14]. The standardized precipitation index (SPI) [15] tool, recommended by the World Meteorological Organization (WMO) and is widely used for quantifying the precipitation deficit over different timescales. The method improves the common anomaly method, which does not take into account the fact that rainfall is typically not normally distributed for a cumulative period of 12 months or less.

$$I(i)=\frac{Xi - Xm}{\sigma} \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_ (7)}$$

Where: I(i), x_i, x_m and σ are respectively the standardized index of year i, the value for the year i, the average and the standard deviation of the time series [16]. A positive (+) value indicates an increase over time while a negative (-) value indicates decrease (Tab.1).

Table 1: Standardized precipitation/temperature index (SPI) interpretation.

SPI Value	P- Meaning	T-meaning
2.0 >	extremely wet	extremely cold
1.5 to 1.99	very wet	very col
1.0 to 1.49	moderately wet	moderately cold
−0.99 to 0.99	near normal	near normal
−1 to −1.49	moderately dry	moderately hot
−1.5 to −1.99	severely dry	severely hot
−2 and less	extremely dry	extremely hot

Descriptive statistics were used to analyse the mean, coefficient of variance and confidence level (95.0%) for temperature and rainfall. The equation of the linear regression line is given by:

$Y=ax+b$, ______________ (8)

Where: X = is the independent variable (rainfall) and Y = is the dependent variable (temperature). Slope line = b and intercept = a (value of Y when X=0). The slope of regression describes the trend, whether positive or negative. In this study dependent, variable Y is temperature and independent variable X is rainfall. Linear regression requires the assumption of normal distribution. Thus, the null (H_0) and alternative (H_A) hypotheses states that:

H_0* = *There is no correlation between rainfall /temperature,

H_A* = *There is a correlation between rainfall / temperature.

3 Results and Discussion

3.1 Rainfall trend in Bonaberi-Douala

This study assumes rainfall and temperature as the main determinants of climate variation and change. The Mann Kendall test showed S statistics, Var(S) statistics and Kendall's tau for precipitation were 185.0, 3801.667 and 0.373, respectively at 95% confidence level. The positive value of Kendall's tau and S statistics showed an increasing trend in the time series data of rainfall, similar to studies on variation and trends in precipitation [17]. Var(S) statistics revealed a statistically significant trend over the period of 1985-2016. This revealed that the calculated p-value (0.00) is less than the significance level alpha=0.05, thus the null hypothesis was rejected.

The Standardized precipitation index for Douala (Fig. 2) according to the baseline period, revealed the longest dry period was 1985 to 1993. The driest year was in 2009, while the highest excesses were recorded in 2012 and 2013. This study is similar to the findings of a study done in other central African countries, relating to the fact that inter-annual rainfall is highly variable [18], and this increased vulnerability is in line with Africa at large, in relation to climate change effect [19]. The longest wet period was from 2010 to 2016. Worthy of note is the fact that after the very dry years which were with lowest records, the rest of the years have been wet periods with more years above normal than below. Much of the decreasing trend in rainfall is due to lower rainfall during the severe dry years in the country. The shifts conditions have varied [20] widely depending on the regional perspective on rainfall change (Fig. 2). This was evident for the resulting flood events in 2000, 2001, 2005 and 2013 which led to the death of more than 150 persons, attributed to global warming [21].

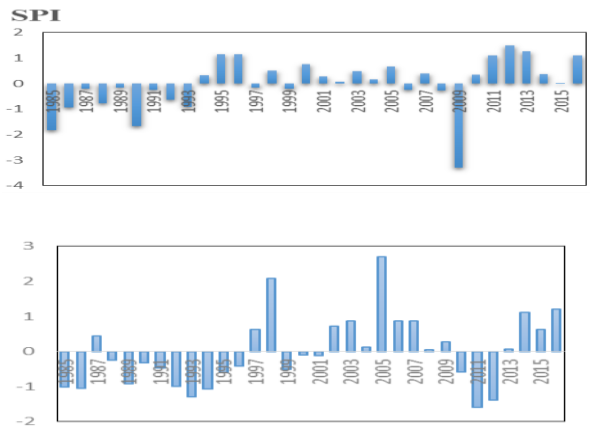

Fig.2: Standardized Precipitation/Temperature Index for annual rainfall in Douala

An increase, decrease or distribution changes in rainfall would influence the water balance, and would alter the frequency of floods [22]. The standardized temperature index (Fig.2) revealed that the longest period with temperatures below normal was from 1988 to 1996. Other periods near normal were recorded as well, but the highest periods above normal was from 2000 to 2009, when it dropped below again from 2010 to 2012 before rising above from 2013 till 2016, while the trends showed the highest period with increase in annual temperature to be from 2002 to 2016, unlike from 1985 to 2001. The almost equal number of years above normal to the stated years below normal shows a warming temperature increase trend in the region and thus more flood hazard possibility (Fig.2). The increase in flood occurrence was attributed to urbanization and climate change. For which small but intense amount of rainfall leads to flood incidences.

3.2 Rainfall trend in Limbe

The Mann Kendall test showed S statistics, Var(S) statistics and Kendall's tau for precipitation were 50, 3802.67 and 0.101, respectively at 95% confidence level. The positive value of Kendall's tau and S statistics showed an increasing trend in the time series data of rainfall From Var(S) statistics, it was revealed that the trend was statistically significant over the period of 1985-2016. The results showed that there is no trend in the rainfall series as p>0.05. The calculated p-value is greater than the significance level (alpha=0.05), therefore accepting the null hypothesis. Studies on rainfall revealed that the African continent exhibits higher inter-annual and intra-seasonal rainfall variability [23-25].

The Standardized precipitation index for Limbe (Fig.3), revealed the longest dry period was 2001 to 2008 which was closely followed by the period of 1991 to 1995. The driest year was in 1991 followed by 2016. Meanwhile, 2013 was the wettest with other excesses being recorded in 2014, 2015 and in 1990 with scenes of flood impacts despite the low rainfall amount recorded, which had resulted to the 1990, 2000, 2001 2013, 2014 and 2015 flood incidences which had more than 205 human lives losses generally. Worthy of note is the fact that after the very dry years which were with lowest records, the rest of the years have been wet periods with the wettest period from 2011 to 2015; but more years below normal than above. The decrease in rainfall is similar to other works that have supported the fact that a decrease in rainfall has occurred abruptly over Central Africa at large in the mid-1970s and the beginning of the 1980s [26], with distribution of the dry and wet years still having droughts by the end of the year 2000 (Fig. 3).

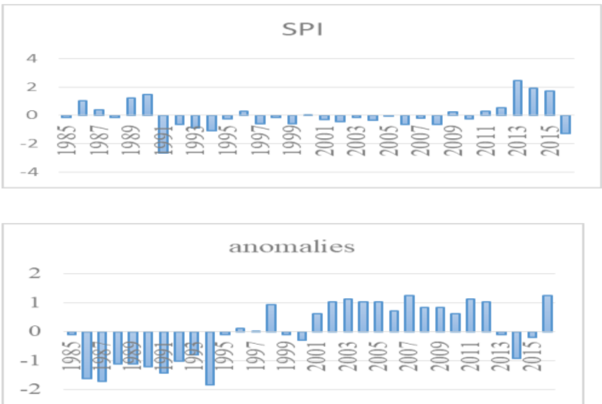

Fig. 3: Standardized precipitation index for annual rainfall in Limbe

The maximum and minimum temperatures were 27.3℃ and 24.6℃ respectively. The average temperature was given as 24.24℃, revealing a significant rising temperature trend with maximum temperature above the average. The standardized temperatures index anomalies revealed that the longest period with temperatures below normal was from 1985 to 1994. The highest periods recorded above normal was from 2001 to 2012. Meanwhile the trends showed the highest period below normal was from 1985 to1995 (Fig.3 Generally, the years above normal show a warming temperature increase trend in recent times and this was attributed to increase in anthropogenic activities [27].

3.3 Annual temperature relationship assessment

The result indicated that the amount of temperature in these areas was variable. Based on the relationship analyses between annual temperature variations in the areas, the student statistical test showed a 95% significance threshold (Fig.4). This was attributed to the ever-rising population and poor urbanization planning policy implementation within the sites, as houses are built within water pathways with increased deforestation and land reclamations of water locked areas. This is similar to [28] the Western highlands of Cameroon describing high fluctuations in average temperatures over the last 12 years and another result of 0.2 °C temperature increasing annually [29] (Fig.4).

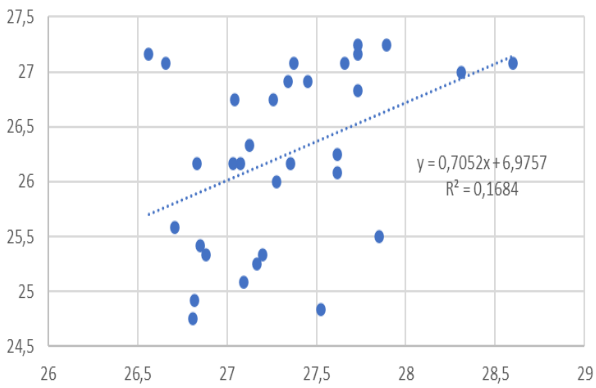

Fig. 4: Relationship between annual temperature of Douala and Limbe

There exists a positive correlation between variations in rainfall for Douala and Limbe (Fig.5). The relationship between annual variations in rainfall presented a significant statistical test (threshold of 95%) and a correlation coefficient of R-0.037. This could be attributed to the reduction in water bodies and the increased production of greenhouse gases which have led to the changing climate. The findings are similar to other research [30, 31] on rainfall reduction and temperature relationships revealing that cold years were mostly wet and warm years were drier; thus, the considerable interest in variability and trends in rainfall and temperature (Fig.5). It is worth noting that urbanization has modified the flood patterns over the years, leading to variability in the amounts, evident in the fact that for Limbe (315.605 mm) the maximum and minimum records were 536.350 mm and 73.183 mm respectively on average, while it was 363.950 mm maximum and 70.125 mm minimum respectively for Douala (272.549mm). The low rainfall amount recorded in Douala is attributed to the high rate of industrial pollution within the city.

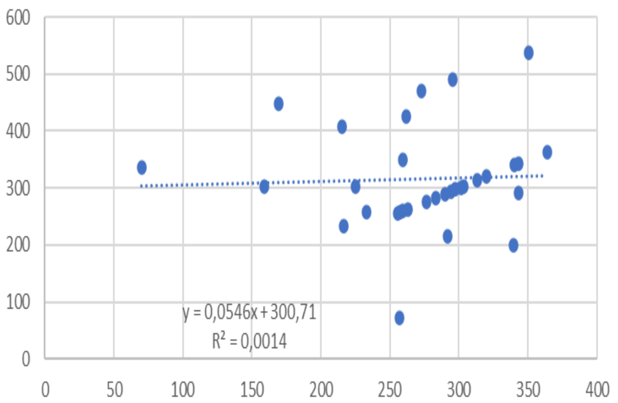

Fig.5: Relationship between annual rainfall of Douala and Limbe

The relationship between annual variations in precipitation and temperatures in the city of Limbe (Fig.6), shows a very small negative correlation (R-0.11) indicating a low inter-dependence between inter-annual variations in precipitation and temperatures in the city of Limbe (Fig.6). Climatic models have predicted the rainfall trend in similar communities under global warming and pointed to a decreasing daily rainfall [32] and increasing temperature [33, 34].

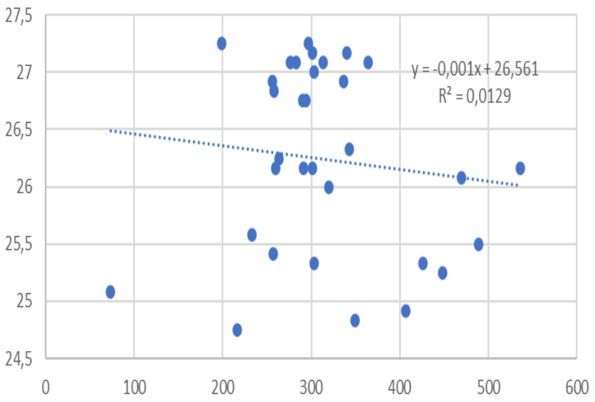

Fig. 6: Relationship between annual rainfall and temperature for Limbe

Upon assessing the relationship between annual variations in rainfall and temperatures in the communities of Douala (Fig.7), the results showed a very small negative correlation (R-0.09) indicating a low inter-dependence between annual variations in precipitation and temperatures within the city. When temperature increases in Douala, rainfall also increases, attributed to climate change, which causes increased evaporation leading to more rain, industrialization, and construction. The variation in rainfall agrees with other analyses [35], which projected a reduction in rainfall on average between 2.8 % and 10.9 % by 2050.

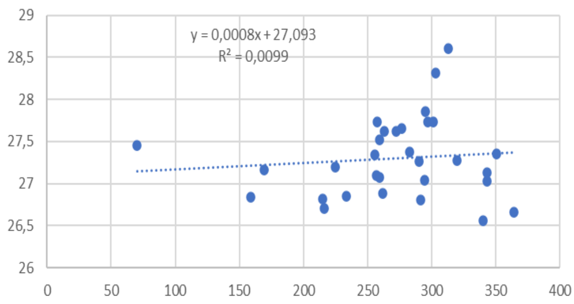

Fig. 7: Relationship between annual rainfall and temperature for Douala

3.6 Anomalies variations

3.6.1 Annual temperature anomalies Limbe

These results are in line with previous research findings [36], stating that the temperatures of Eastern Africa in the 1990 periods have been warmest and are currently changing compared to historical times. Assessing temperature anomalies showed that the period from 1986 to 1994 were the coldest while the years 1998, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, and 2012 were warm, with the year 2016 being the hottest (Fig.8). The mean annual temperature is expected to increase with reduction in amount of cooling nights [37, 38].

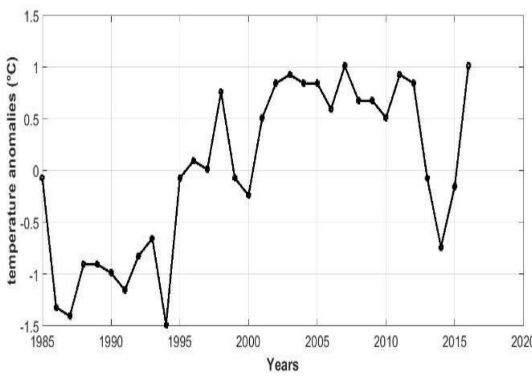

Fig. 8: Annual anomalies temperature variations Limbe

3.6.2 Monthly anomalies of temperatures Limbe

The monthly anomalies of temperatures in Limbe, shows the warm months were recorded to be November, December, January, February, March and April, with December being the warmest month while the coldest month recorded was July, with other cold periods being recorded from the months of June, August and September (Fig.9). This report is in accordance with other reports [39], which showed March, April, June, November and December being hot months with slight changes from historical trends. In view of the results, most significant impacts of climate change are likely to have arisen from shifts in the intensity, frequency, and duration of extreme weather events and the anthropogenic nature (Fig.9); thus, temperature has increased, and particularly warmed in the dry season [40]. Other researchers globally, and over Africa [41, 42] have reported a similar increase in temperature.

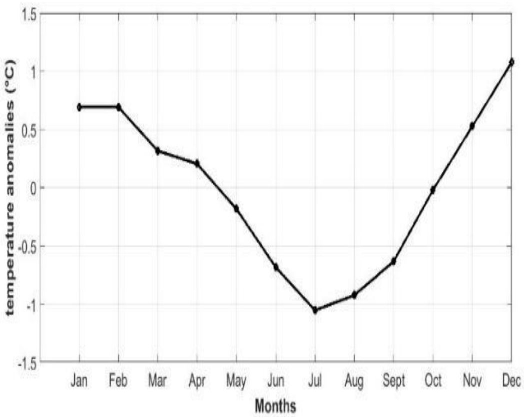

Fig.9: seasonal anomalies temperature variations Limbe

The rainfall situation upon anomaly assessment showed that the driest year recorded was in 1991 and the wettest year was recorded in 2013. The year 2001 recorded a drop from the 2000 amount although it was the worst year in terms of destruction as landslides and flooding disasters led to loss of lives and properties within the city. Similar research [43, 42] reported on delays in the inter-annual rainfall with a decrease in the amount. On the other hand, the average rainfall from 1995 to 2010 was marked by the same evolutionary trend (Fig.10), still due to its fragile natural ecosystems, the lifestyle of the people, and the economic situation, making it extremely sensitive to climate changes.

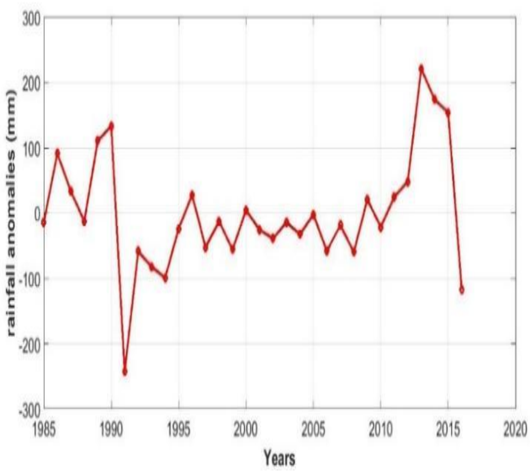

Fig. 10: Annual rainfall anomalies variations Limbe

The monthly anomalies of the rains in the city of Limbe, showed that rainy season starts from the months of March, April and May, while the typical rainy season is recorded from the months of June, July, August, September and October, which seem to be the period with the highest flooding events after a long period of rainfall. Also, these findings are similar to other studies, [44] which have realized similar trends in the onset of the rainy season and [45] another which reported on rainfall continuity until September, but not as heavy as in June, July and sometimes August. The dry season is recorded from November to February (Fig.11) during which the affected inhabitants recover, for which the middle of 21st century's annual average rainfall will be decreased by 10–30 % [46].

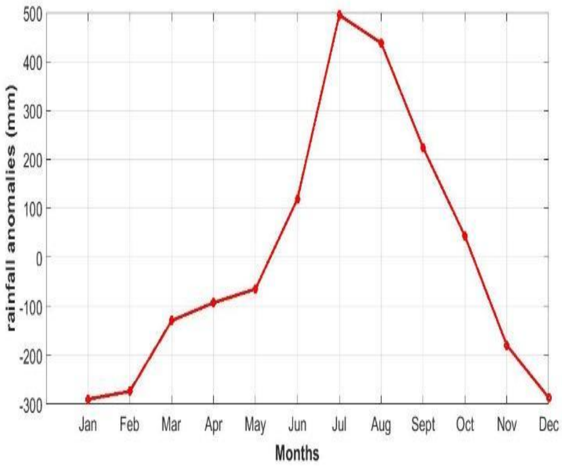

Fig. 11: Seasonal rainfall anomalies variations Limbe

3.7 Relationship between climatic variables and flood pattern

The relationship between seasonal variations in precipitation and temperatures in the cities of Limbe further showed a strong negative correlation (R-0.95), indicating that the periods of heavy precipitation corresponded to periods of low temperatures in the city of Limbe (Fig.12). Generally, it is believed that extreme flood events will occur more frequently due to changes in climate and land use change [47, 48]. The results further revealed that the cooler months tend to be associated with more rainfall while the drier months had less rainfall amounts, mainly in terms of the frequency of occurrence and its abundance. Flooding events in Limbe city coincided to peak periods of rainfall and temperature in these localities.

Limbe has recorded significant flooding events such as the 2001 floods, which caused disruption of socio-economic activities, extensive damage to property, infrastructure, communication facilities, and loss of lives. A similar applicable study [49], holding that if the current temperature/rainfall relationships remain unchanged in the study area, warmer years will most likely be linked to a decrease in rainfall [46] just as it is with the selected areas for this study (Fig.12).

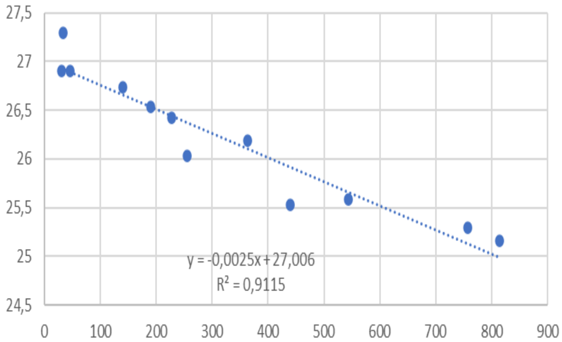

Fig. 12: Relationship between monthly rainfall and temperature for Limbe

The monthly variations in precipitation and temperatures in the cities of Douala, showed a strong negative correlation (R-0.91) indicating that periods of heavy rainfall which are often associated with flooding [50] correspond to periods of low temperatures in the city of Douala (Fig.13).

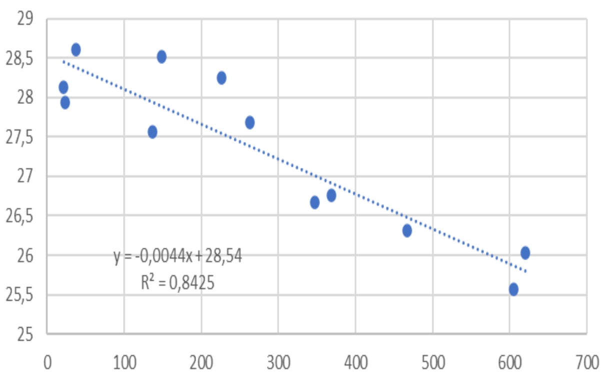

Fig.13: Relationship between monthly rainfall and temperature for Douala

The annual temperature records for Douala clearly indicate that temperature trends over the studied period are not consistent between seasons [36]. Assessing temperature anomalies in the city shows that 1993, 2011 and 2012 were the coldest, while 1998 and 2005 were the warmest years (Fig.14). Thus, an increase in urbanization and housing infrastructures with deforestation will mean a rising temperature which will lead to more evaporation and high flooding events.

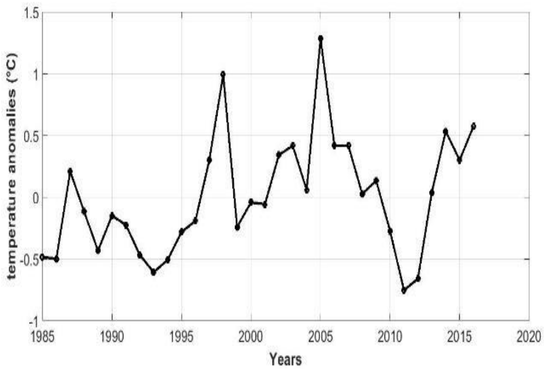

Fig. 14: Annual temperature anomalies variations Douala

The analyses of monthly anomalies for temperatures in the city of Douala, showed that the warm months were recorded in December, January, February, March and April, with February being the warmest month, while the coldest month recorded was in August, but other cold periods were recorded from the months of June, July, August, September and October (Fig.15). The Minimum temperatures ranged from 23 °C to 27°C, and Maximum temperatures ranged from 27°C to 31°C, with the min temperatures for Douala being lowest in February and highest in March unlike in Limbe where the min temperature was lowest in September and highest in December. For the Max temperature, the records for Douala showed highest in April while for Limbe its highest in February (similar to April, May, November and December), meanwhile the temperatures are in line with studies on temperature variability [51, 43]. Some main reasons accounted for the variation is the increasing urbanization and poor planning as settlement increase leads to forest losses and this might be the case that temperature is increasing from time to time as a result of global climate change (Fig.15).

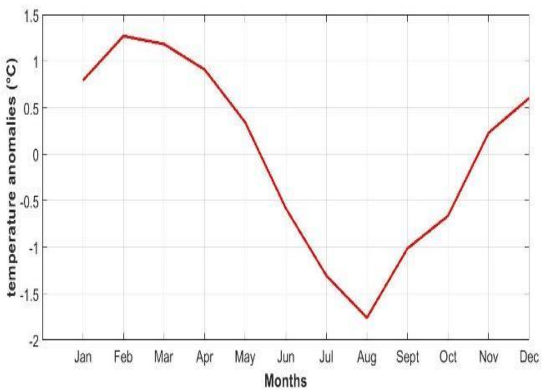

Fig. 15: Seasonal temperature anomalies variations Douala

The rainfall anomaly of the city of Douala showed that the driest year was recorded in 2009 and the wettest year was in 2012 during which the wetness accounted for the saturation that led to the 2012 flooding. On the other hand, it revealed that average rainfall from 1997 to 2008 was marked by the same evolutionary trend (Fig.16). One possibility is that the observations for Douala are not homogeneous in time conceivably for the times of collection which encountered poor functioning of the equipment and the degree of suburbanisation. In 2015, the situation in Douala was such that many lives and properties were also lost with health impacts on an increase, displacing 2000 people, increased death rate from fallen electric poles and malaria. This triggered concerns for climatic trends and flood pattern interpretations. Two main reasons such as the increasing number of floods presumably due to climate change; and the large city sizes, which are rapidly growing in number, accounted for flood increase since the frequency, intensity, duration and spatial coverage of these extremes are expected to be amplified [52, 7].

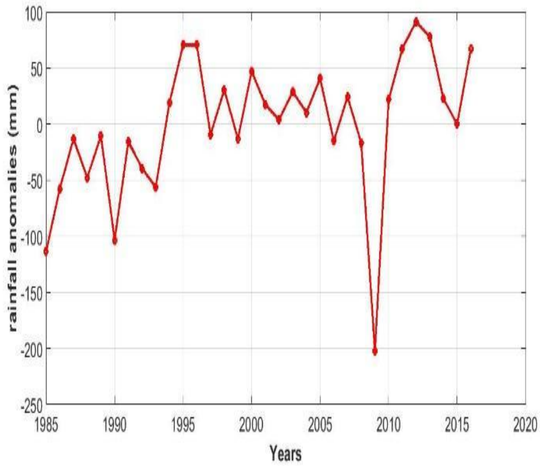

Fig. 16: Annual rainfall anomalies variations Douala

The monthly anomalies for rainfall in Douala showed that the lesser rainy season is recorded during the months of March, April and May, while the excessive rainy season is recorded from the months of June, July, August, September and October, during which July and August are usually the peak flooded expectant months with the greatest impact on these vulnerable communities. The dry season is recorded from November to February (Fig.17) and are often warmer in recent years.

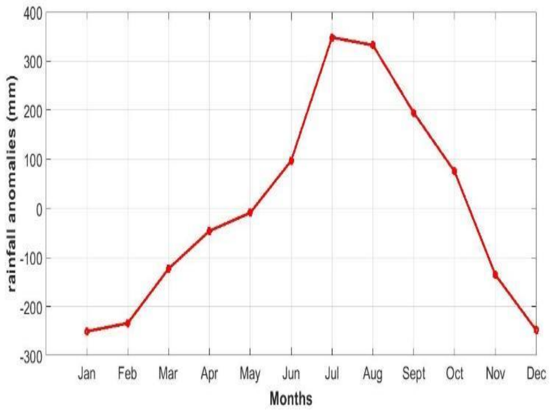

Fig. 17: Seasonal rainfall anomalies variations Douala

Assessing the relationship between monthly variations in precipitation in the cities of Douala and Limbe, shows a very strong positive correlation (R-0.99) between seasonal variations in precipitation between Douala and Limbe. Some research results [53, 39] have shown positive correlations in their studies. Periods of heavy rainfall in Douala correspond to periods of heavy rainfall in Limbe (Fig.18), with similar periods of flood events. These evidences are true in ground truthing, with the onset of the rainy season having some warm and wet periods as these cities belong to the equatorial climate zone and of the tropical rainforest with some areas having almost unpredictable rains due to the climatic variations and closeness to the sea and other factors like Sea level rise and deforestation (Fig.18). In recent times, incidence of climate change related hazards has manifested in the form of recurrent rainfall variability and flood events [54, 55]. Thus, managerial measures are to be implemented following the results of this study.

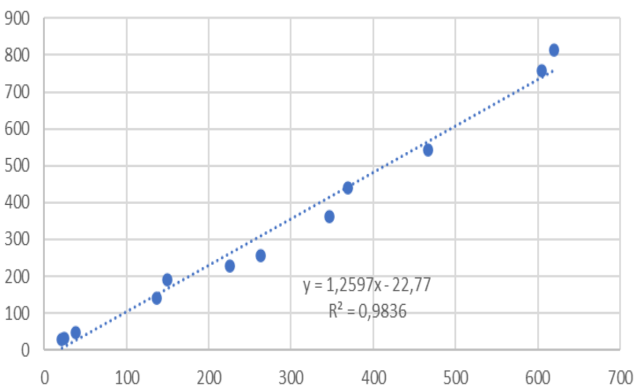

Fig. 18: Monthly rainfall variations for Douala and Limbe

4 Conclusion

The study sites are vulnerable to climate variability, and climate change is likely to increase the frequency and magnitude of disasters such as flooding. Past and current flood disaster interventions in the areas are more focused on recovery from a disaster than on the creation of adaptive capacity or preventive measures, thus the outcome of this study holds that the annual (long) time scale correlation of rainfall and temperature results in a negative correlation. The interannual and seasonal trends of precipitation were investigated by the Mann–Kendall test, the Sen's slope estimator and the linear regression. Therefore, when temperature decreases rainfall is high and thus more flooding in the peak rainfall periods, when warm years were apparent the resulting effect was a reduction in rainfall. For this purpose, records from rain gauge stations over Douala and Limbe for the period of 1985– 2016 were analysed. The Sen Slope results exhibited that the annual and seasonal temperature had an increased trend. Analysis of annual and seasonal temperature also showed varying trends. The standardized temperature index for Douala revealed the longest period with temperatures below normal was from 1988 to 1996 and the highest periods above normal was from 2000 to 2009, while the trends showed the highest period with increase in annual temperature to be from 2002 to 2016. In Limbe, the longest period with temperatures below normal was from 1985 to 1994. The highest periods recorded above normal was from 2001 to 2012. July and August are the coldest months with more rainfall amounts and flooding events. The highest average rainfall (Douala) was in 2012 and 2013, 1995 and 1996, being lowest in 2009. For Limbe, the situation shows rainfall average was highest in 2013 followed by 2014 and lowest in 1991.
The positive correlation coefficients were found to result from correlation on a monthly (short) time scale. This could be explained from the fact that monthly data for temperature and rainfall behave in the same manner, for example, in August and July when they are highest with the peak flood intervals like the 2001 and 2019 events in the study sites.

As the study area experiences a high degree of annual rainfall variability with dry and wet years alternating frequently, careful management of water resources is a high priority such that flooding impacts could be controlled towards reducing the impacts of these phenomena on the populations within these areas The study revealed the fact that a decrease in rainfall has occurred abruptly over Douala, Limbe and Central Africa at large in recent years, related to some major climatic disturbances with respect high rainfall totals, associated with more flooding events.

Also, flood risk within the study sites is attributed to human factors like urbanization, as major cities have more impermeable surfaces. Due to deforestation impact on water interception and increases run-off.
Thus, to better the findings, further studies on rainfall with longer data sets need to be done for more understanding and forecast of rainfall variability with temperature changes. Regarding some uncertainties arising from the variability of temperature and rainfall, water and municipal managers and communities should come up with alternative and sustainable sources of water, example like developing groundwater sources, which will assist in averting the negative impact associated with water contamination and diseases prevalence. Results from risk assessment and land use patterns could be used to make posters that can be made public for inhabitants to have awareness and actually see risk zones.

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References:

[1] Balgah R.A. & Buchenrieder G., 2011, 'Does technology adoption reduce risks for smallholder farmers in Cameroon?' Pakistan Journal of Social Sciences8(1),13–22.
http://dx.doi.org/10.3923/pjssci.2011.13.22
[2] Guha-Sapir D., Vos F., Below R. & Ponserre S., 2011, Annual disaster statistical review. The numbers and trends, Center for Research on the Epidemiology of Disasters (CRED), Brussels.
[3] Guha-Sapir D., Hoyois P.H. & Below R., 2014, Annual disaster statistical review. The numbers and trends, Center for Research on the Epidemiology of Disasters (CRED), Brussels.
[4] Buishand, T. A and Brandsma, T., 1999. Dependence of precipitation on temperature at Florence and Livorno (Italy). Climate Research, 12, 53–63.

[5] Macatsha, N., 2006. Water Quality Monitoring in the SADC region. Published Master of Science in Engineering Thesis, University of Witwatersrand, South Africa.
[6] Foreman, W. (2012). Protecting people from deadly floods, quakes in the Philippines. University of Michigan News Service.
http://ns.umich.edu/new/releases/20235 protecting-people-from-deadly-floods quakes-in-the Philippines
[7] Chu, J. (2012) MIT News: More Powerful Devastating Storms to Come Due to Climate Change. MIT News, Quantum Day.
http://www.quantumday.com/2012/02/mit-news-more-powerful-devastating.html©Commonwealth Secretariat 2018.
[8] Hartmann, D. L., Klein Tank, A. M. G., Rusticucci, M., Alexander, L. V., Bronnimann S., Charabi, Y. A. R., Dentener, F. J., Dlugokencky, E. J., Easterling, D. R., Kaplan, A., Soden, B. J., Thorne, $ Zhai, P. (2013). Observations: Atmosphere and surface. In climate change 2013 the physical science basis: Working group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Vol. 9781107057999, pp. 159-254). Cambridge University Press. https://doi.org/10.1017/CBO9781107415324.008
[9] Awum, D., Kamanda, B., Ndongo, F., (2001). Mainstreaming potentials for sustainable development in Limbe Urban Municipality, Yaoundé.http://www.unhabitat.org/offices/roaas/france/limbe.pdf.
[10] Zogning. A, Spinetti, C., Ngouanet, C., Tchoudam, D., Thierry, P., Bignami, C., Kouokam, E., Buongiorno, M. F., Ilaria, M. and Apa, P., (2009). Risks Prevention Plans (RPP) and the vulnerability of peoples around volcanoes: Case study of Mt. Cameroon. Proceedings of the First international conference "Volcanoes, Landscapes and cultures", 11-14/11/2009, Catania, Italy
[11] Mann, H.B., “Non-parametric test against trend”, Econometrica 13, 245 –259 (1945).
[12] Kendall, M.G., “Rank Correlation Methods”, 4th edition. Charles Griffin, London, UK (1975)
[13] Sen, P.K.L. otAsa Estimates of the regression coefficient based on Kendall's tau. J. Am. Stat. Assoc.1968, 63, 1379-1389.
[14] Partal, T., Kahya, E., 2006. Trend analysis in Turkish precipitation data. Hydrol. Process. 20, 2011–2026. http://dx.doi.org/10.1002/hyp.5993.
[15] Mckee, T.B.; Doesken, N.J.; Kleist, J. The relationship of drought frequency and duration to time scales. In Proceedings of the Eighth Conference on Applied Climatology, Anaheim, CA, USA, 17–22 January 1993; pp. 179–184
[16] WMO. Standardized Precipitation Index User Guide; Svoboda, M., Hayes, M., Wood, D., Eds.; WMO: Geneva, Switzerland, 2012.
[17] Irannezhad M., Marttila H., Kløve B. 2014 Long-term variations and trends in precipitation in Finland. Int. J. Climatol. 34 (10), 3139–3153.
[18] Masumbuko, B. and Somda, J. (2014). Analysis of the links between climate change, protected areas and communities in West Africa. UNEP-WCMC technical report.
http://parcc.protectedplanet.net/en/regional-and-national-activities/linksbetween-pas communities-and-climate-change.
[19] Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R.Tabo, and P.Yanda, 2007: Africa. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 433-467.
[20] Rosell, S. 2011 Regional perspective on rainfall change and variability in the central highlands of Ethiopia, 1978–2007. Appl. Geogr. 31, 329–338.
[21] Hulme M., Doherty R., Ngara T., New M., Lister D. 2005 Global warming and African climate change: a reassessment. Clim. Change Afr. 29–40
[22] KumarV. JainS. K. SinghY. 2010 Analysis of long-term rainfall trends in India. Hydrol. Sci. J. 55, 484–496.
[23] ChallinorA. WheelerT. GarforthC. CraufurdP. KassamA. 2007 Assessing the vulnerability of food crop systems in Africa to climate change. Clim. Change 83, 381–399.
[24] Cooper P. RaoK. P. C. SinghP. DimesJ. TraoreP. S. RaoK. DixitP. TwomlowS. J. 2009 Farming with current and future climate risk: advancing a ‘Hypothesis of Hope’ for rainfed agriculture in the semi-arid tropics. J. SAT Agric. Res. 7, 1–19.
[25] Cooper P. J. M. CoeR. SternR. D. 2011 Assessing and addressing climate-induced risk in Sub-Saharan rainfed agriculture. Exp. Agric. 47, 179–410
[26] L’Hote, Y., Mahe, G., and B.Some B.,and Triboulet, J.P., 2002: Analysis of a Sahelian annual rainfall index updated from 1896 to 2000; the drought still goes on. Hydrol. Sci. J, 47-4,563-572.
[27] World Bank (2010). Economics of adaptation to climate change, Ethiopia. World Bank Group 1818 H Street, NW Washington, DC 20433.
[28] Yengoh, G. T., Armah, F. A., $ Svensson, M. G. E. (2010). Technology adoption in small-scale

agriculture. Science, Technology $ Innovation Studies, 5(2), 111-131.
[29] Mebratu K, Johannes GM (2009) Local innovation in climate change adaptation by Ethiopian pastoralists. PROLINNOVA-report, Addis Ababa, Ethiopia
[30] Madden, R. A, and Williams, J, 1978: The correlation between temperature and precipitation in the United States and Europe, Monitory Weather Review No. 106, pp 142-147.
[31] Nkiaka, E., Nawaz, N. R. & Lovett, J. C. Analysis of rainfall variability in the Logone catchment, Lake Chad basin. Int. J. Climatol. 37, 3553–3564, https://doi.org/10.1002/joc.4936 (2017).
[32] Maúre, G, Pinto, I, Ndebele-Murisa, M, Muthige, M, Lennard, C, Nikulin, G, Meque, A, et al. 2018. The southern African climate under 1.5 C and 2 C of global warming as simulated by CORDEX regional climate models. Environmental Research Letters, 13(6): 065002.
DOI: https://doi.org/10.1088/1748-9326/aab19
[33] Nangombe, S, Zhou, T, Zhang, W, Wu, B, Hu, S, Zou, L and Li, D. 2018. Record-breaking climate extremes in Africa under stabilized 1.5 C and 2 C global warming scenarios. Nature Climate Change, 8(5): 375. DOI:
https://doi.org/10.1038/s41558-018-0145-6
[34] Nikulin, G, Lennard, C, Dosio, A, Kjellström, E, Chen, Y, Hänsler, A, van Meijgaard, E, et al. 2018. The effects of 1.5 and 2 degrees of global warming on Africa in the CORDEX ensemble. Environmental Research Letters, 13(6): 065003.
DOI: https://doi.org/10.1088/1748-9326/aab1b1
[35] Environmental Protection Agency. 2015. Ghana's Third National Communication Report to the UNFCCC.
[36] Hulme, M., Doherty, R., Ngara, T., New, M. and Lister, D. (2001), "African climate change: 1900-2100", Climate Research, Vol. 17, pp. 145-168.
[37] McSweeney, C., M. New, and G. Lizcano (2015), UNDP climate change country profiles – Ghana. [Available at http://ncp.undp.org/ documents/undp-climate-change-country-profile-11 Accessed on May 20, 2015.
[38] Tachie-Obeng, E., E. Gyasi, S. Adiku, M. Abekoe, and G. Ziervogel (2010), Farmers' adaptation measures in scenarios of climate change for maizeproduction in semi-arid zones of Ghana, ICID + 18 2nd International Conference: Climate, Sustainability and Development in Semi-arid Regions, Fortaleza - Ceará, Brazil.
[39] Molua EL, 2006. Climate Trends in Cameroon: Implications for Agricultural management. Climate Research 30: 255-262.
[40] Beniston M, Stephenson DB (2004) Extreme climatic events and their evolution under changing climatic conditions. Glob Planet Change 44:1–9
[41] Collins, J. M. Temperature Variability over Africa. Journal of Climate 24, 3649–3666, https://doi.org/10.1175/2011JCLI3753.1 (2011).
[42] IPCC. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Inter-governmental Panel on Climate Change 1535 (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013).
[43] Molua EL, 2002. Climate Variability, Vulnerability and Effectiveness of farm-Level Adaptation Options: The Challenges and Implications for Food Security in Rural Cameroon. Journal of Environment and Development Economics 7 (3): 529-545.
[44] Buh, W. G., (2009). Geographic information systems-based demarcation of risk zones: The case of Limbe Sub-Division-Cameroon, Journal of Disaster Risk Studies. Vol. 2, No. 1: 54-70.
[45] Cheo, A.E., Voigt, H-J, Mbua, R.L. (2013) Vulnerability of water resources in northern Cameroon in the context of climate change. Environ Earth Sci. (2013) 70:1211–1217.
[46] IPCC (2007). "Climate Change 2007: Impacts, Adaptation and Vulnerability," In: M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, Eds., Contribution of Working Group II to the Fourth Assessment Rep Change (IPCC), Cambridge 2007
[47] Reynard, N. S., Prudhomme, C. and Crooks, S. M. (2001): The Flood Characteristics of Large UK Rivers: Potential Effects of Changing Climate and Land Use. Climate Change 48: 343-359.
[48] Brown, J. D. and Damery, S. L. (2002): Managing Flood Risk in the UK: Towards an Integration of Social and Technical Perspectives. Transactions of the Institute of British Geographers 27: 412-426.
[49] Trenberth, K.E and Shea, D.J, 2010: Relationships between precipitation and surface temperature, Geophysical Research Letters, Vol. 32, National Centre for Atmospheric Research, Boulder, Colorado, USA, pp 54.
[50] Llasat M.C. et al., 2013. Towards a database on societal impact of Mediterranean floods within the framework of the HYMEX project. Natural Hazards Earth System Sciences, 13: 1337–1350.
[51] Singo, L.R, 2008: Temporal characteristics of rainfall and their influence on river discharge: The case of the Luvuvhu River Catchment in the Limpopo Province of South Africa. Master's dissertation in

Hydrology and Water Resources. University of Venda, South Africa.
[52] Seneviratne, S. I., et al. (2012), changes in climate extremes and their impacts on the natural physical environment, in Managing the Risk of Extreme Events and Disasters To Advance Climate Change Adaptation, A Special Report Of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC), edited by C, B. Field et al., pp.109-230, Cambridge Univ. Press, Cambridge UK, and New York, NY, USA.
[53] NASA, 2002: Climate Change; 50 years Past and Possible Futures, New York City Press, New York.
[54] Kenabatho P., Parida B., Moalafhi D. 2012 The value of large-scale climate variables in climate change assessment: the case of Botswana's rainfall. Phys. Chem. Earth A/B/C 50, 64–71.
[55] Meshesha T. W., Tripathi S., Khare D. 2016 Analyses of land use and land cover change dynamics using GIS and remote sensing during 1984 and 2015 in the Beressa Watershed Northern Central Highland of Ethiopia