

RAINFALL PATTERN IN FREETOWN, SIERRA LEONE: FROM A RETROSPECTIVE VIEWPOINT

E. T. Taylor¹, I. S. Kamara², A. Bockarie²

¹ Institute of Environmental Management and Quality Control, School of Environmental Sciences, Njala Campus, Njala University, Moyamba District, Private Mail Bag, Sierra Leone

² Sierra Leone Meteorological Department, F18 Charlotte Street, Freetown, Sierra Leone

Abstract

Introduction and Purpose: It is now apparent that the changing weather patterns are associated with climate change according to the UN Intergovernmental Panel on Climate Change. In the wake of relatively little work looking at rainfall pattern in tropical countries of developing nations, especially in Sierra Leone, we conducted a retrospective analysis on the amount of rainfall over the past few decades for Freetown, the capital of Sierra Leone.

Methods: Annual rainfall data from 1960-2009 were obtained from the Sierra Leone Meteorological Department (SLMD). Average monthly and total yearly rainfall data were calculated for five decades (1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009).

Results: It was revealed that August had the highest amount of precipitation and a constant fluctuation of total annual rainfall around the mean was observed. There was no significant difference among the average total rainfall for the five decades. With a seemingly decline in average total rainfall, there are signs of increased rainfall in the last decade (2000-2009) probably due to a combination of factors, among which includes an increase in cloud condensation nuclei that are mainly derived from anthropogenic input through combustion activities.

Conclusion: The study revealed marked variation in total rainfall pattern around the mean in Freetown over the past half century.

Keywords: Rainfall Pattern; Data Scarcity; Climate Change; Sierra Leone

Corresponding Author's Contact:

Emails: etaylor@njala.edu.sl; elduredo@gmail.com;

Tel: +232-76-717708

Introduction

The sustenance of many ecosystems largely depends on the availability of water, a precious resource. More importantly, rain water is an intrinsic valuable alternative resource in most parts of the world [1-5]. As this precious resource has diverse uses ranging from, domestic to commercial and to agriculture in tropical countries, it is undoubtedly true that it is very essential for human societies and their economies. For instance, the agricultural sector in Sierra Leone musters about 70% of the work force and accounts for more than half of the GDP, as of 2007, and crop production largely depends on rainfed agriculture. Hence, reliance of crops with the increased evidence of a changing climate as indicated in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, makes productivity output highly variable as the onset and cessation of rain are subject to space and time [6].

A handful of detailed studies on rainfall variability have been reported in the sub region [6-8], but none about Sierra Leone has been reported so far to our knowledge. All of these regional studies showed variation in rainfall pattern whether increasing or decreasing trends or the onset and cessation of rains. For instance, [6] showed a significant trend towards earlier cessation dates of summer rains for a period of over 40 years from 1950-1992 but other studies revealed a trend towards delayed onset and early cessation that resulted to shorter rainy spell [9-10].

In a recent report, Sierra Leone was reported to be experiencing climate variability as evident in rainfall anomalies. This observed variation was also noted in the second part of the national communication report [11]. As Sierra Leone is reported to be vulnerable to climate change, the intensity and frequency of rainfall variability is expected to be more evident. In recent times, there have been periods of delay in rains and associated water shortages mostly in Freetown, an indicator of rainfall variability. With such visible signs of our changing climate, the need to conduct a retrospective analysis on rainfall pattern cannot be overemphasized. Thus, the pattern of rainfall variability over the past fifty years was examined to understand the temporal changes (inter decadal changes).

Methods

Freetown is the commercial capital of Sierra Leone and is located on the West Coast of the country on a mountain peninsula stretching down to the Atlantic Ocean, with elevation that stretches from 11m to over 100m above sea level depending on the location and conservative current estimate of the population of the city stands at 1,200,000.

The climate is tropical and humid and controlled largely by the Tropical air mass affecting the entire sub-region as a whole. This main type air mass can be further sub divided into Tropical Continental and Tropical Maritime. The movement of the Inter Tropical Convergence Zone (ITCZ) largely controls the seasonal variation in West Africa. As Sierra Leone is close to the maximum poleward position of the ITCZ, only one rainy season is observed (May-October) and as the ITCZ moves away from this position brings in another season that is the dry season (November-April).

Rainfall data were acquired from the Sierra Leone Meteorological Department (SLMD) for Freetown and covered the period 1960-2009. In a way to establish changes in rainfall, the temporal variation of total rainfall in Freetown for each year (1960-2009) was computed, and the mean total yearly rainfall was calculated for five decades (1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009). Mean monthly rainfall for the entire period was determined so as to understand rainfall distribution over the period. Mean temperature for the decades 1980-1989; 1990-1999; 2000-2009 were computed so as to observe the change in mean temperature over this period.

Results and discussion

The months of July, August and September are noted to have significant precipitation with August observed to be the wettest month for the different decades *Figure 1*. This period is often characterized by recharge of surface and sub surfaces reservoirs. It is evident from Figure 1 that the mean monthly rainfall follow a similar pattern for July, August and September for the five decades.

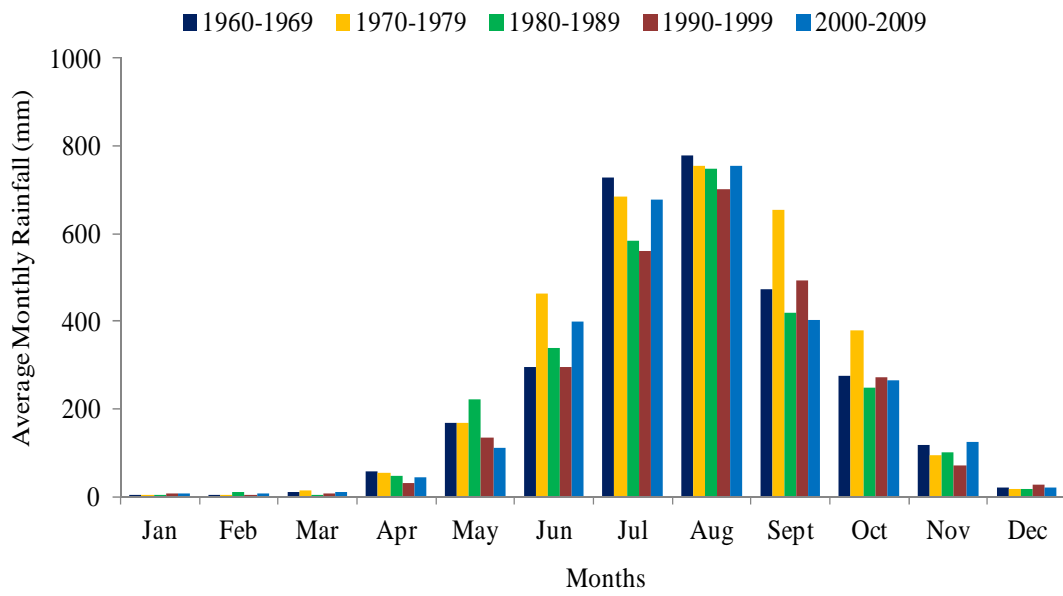


Figure 1. Mean monthly rainfall distribution for Freetown for the different decades

From *Figure 2*, the temporal variation indicated an undulated but downward rainfall pattern in the 60's leading to the 70's with an increase in precipitation (10.8%) during the 70's. Following this period saw a gradual decrease in precipitation (20.7%) leading to the 90's. A noticeable increase in rainfall was observed in the 90's peaking around 1995 in contrast to earlier periods and then dropped considerably around 2000, but a steady increase (7.9%) in rainfall between the decade of 1990-1999 and that of 2000-2009 has been observed. Evidently, there is variation in the amount of rainfall in Freetown, Sierra Leone, an indication of a changing climate over the years.

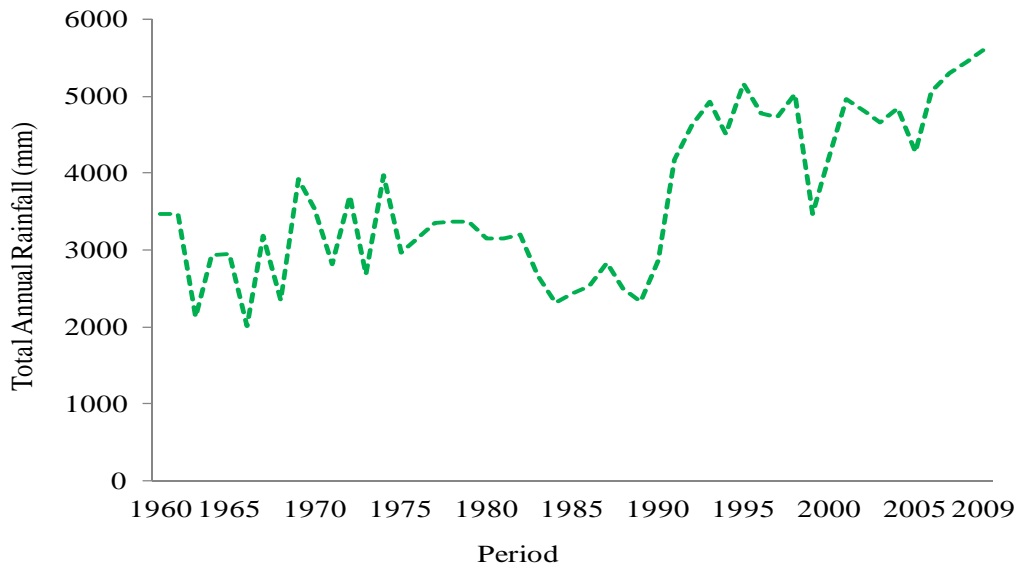


Figure 2. Temporal variation of total rainfall in Freetown between 1960 and 2009

The trend in *Figure 2* showed a constant fluctuation of total rainfall around the mean (2882mm). It is increasingly becoming clear that the amount of total rainfall is on the increase in the Freetown municipality in recent times which can be ascribed to a combination of anthropogenic induced and meteorological factors. Apparently, there seems to be an enhancement of convection over the city which is more frequent nowadays than it is used to be in the past and this might have resulted to localized downpours over the city. For instance, there is an apparent gradual increase in temperature over the past three decades with (mean temperatures: 1980-1989 is 30.4 °C relative to 2000-2009 which is 30.9 °C) and such observation is in line with a recent report [11]. Such increase would facilitate evaporation particularly in catchment areas that has been deforested. Again the topography of Freetown enhances condensation especially in the mountain tops where it is relatively cooler and this would often forms cloud thereby enhancing precipitation. Further in the country sides, the country breeze is relatively cooler as a result of less industrial activities and low surface heating intensity due to patches of forest canopy relative to that of the urban area. Resultantly is the tendency that the country breeze convergence that flows into the city might also influence the amount of rainfall.

But the large amount of cloud condensation nuclei (CCN) mostly the “*Aitken nuclei that are hygroscopic*” in the atmosphere are mainly generated from anthropogenic input through combustion activities which might be responsible for the increase in precipitation in the latter decade as they facilitate cloud formation. Empirical evidence has indicated that CCN could affect cloud droplet formation [12-14]. Recent evidence suggests that the ambient air in Freetown is confronted with different forms of burning activities [15] which could be a major source of CCN. Given the development pathway that the country is seeking, the release of CCN from industrial and traffic emissions would suggest to continue to increase particularly in Freetown where the engine of growth is centered. Sensitization programs such as capacitating forest rangers so as to reduce human activities in the forest reserve areas by drawing up green belt zones, and encourage tree planting activities around the peninsula might also be additional factors that have enhanced the current rainfall trend although detailed account of this activity needs further investigation.

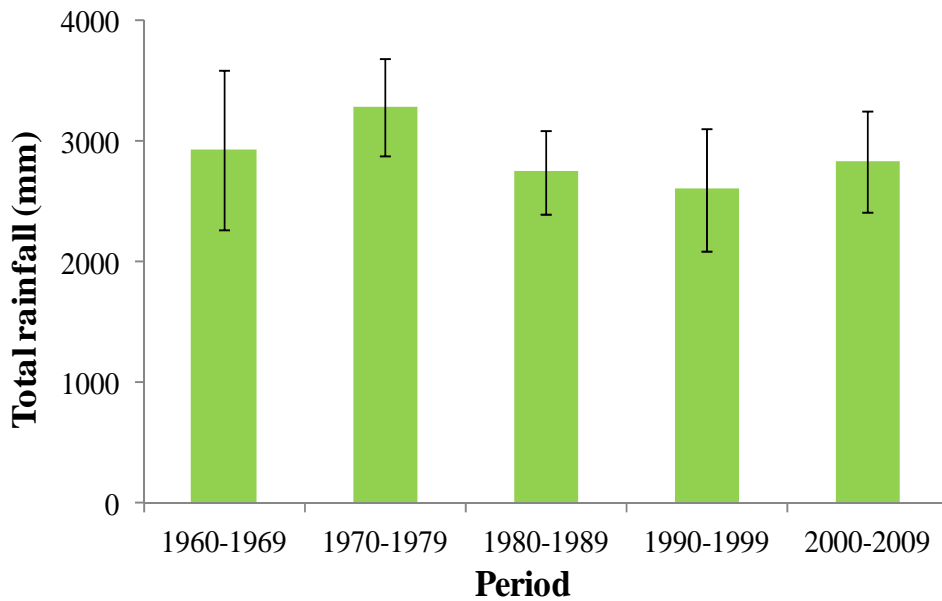


Figure 3. Average total rainfall for the different decades with error bars showing one standard deviation from the mean

Even when the average total rainfall for each decade (*Figure 3*) was considered, there was a seemingly decline in the amount of total rainfall up to the 90's although no significant variation was evident among the bars. Increase in rainfall over the past decade has also been reported in Ghana, a country in the same geographic location [7].

Total rainfall was further examined between pre-civil war period (1960-1989) and during to post civil war period (1990-2009) in Freetown and the analyses revealed a decrease of about (256 mm) or (8.6%) of rainfall during to post civil war period *Figure 4* although the decrease is not significant. Worth mentioning is the uneven representation of the data that were used for comparison. Freetown was considered as safe haven for people during the upheaval and saw the influx of internally displaced people from the interior into the city. This culminated into a social and environmental problem as most of these displaced people could not afford the high rent of residential homes in the central district of the city. This consequently encouraged them to construct makeshift shelters in mountainous areas along the forest reserve as residence. This demographic imbalance has resulted to noticeable deforestation which has been recently reported [16]; and even the patches of forest that are visible on the hills overlooking the city are now under threat due to firewood and charcoal extractions as a means to enhance peoples livelihood. Inadvertently several water catchment areas have been destroyed with water shortage now an acute social problem which is now evident in the long queues to fetch water from public taps.

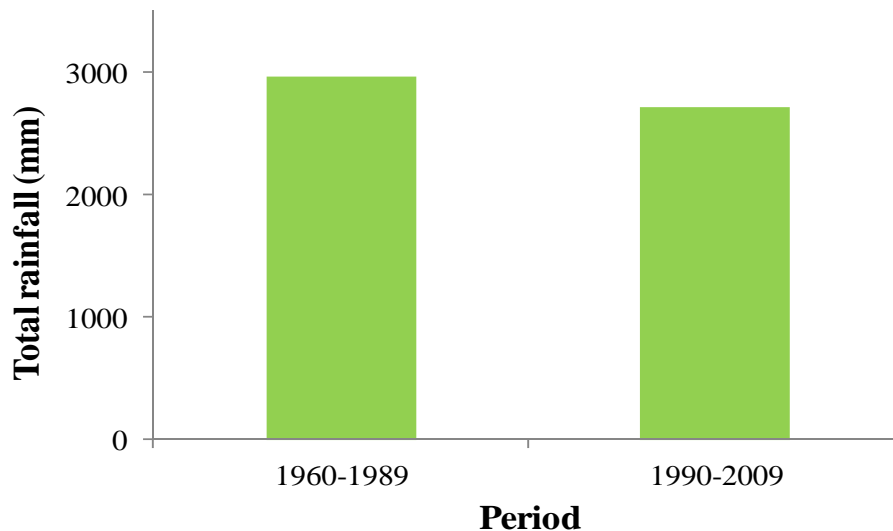


Figure 4. Average total rainfall between pre-civil war (1960-1989) and during and post civil war period (1990-2009)

It is reported that deforestation rate is particularly high in West Africa [17] and would potentially lead to decrease in precipitation leading to vegetation degradation beyond the forest itself [18] suggesting the vulnerability of this region to reduced precipitation as a result of reduced water holding capacity in forested areas. But such observation seems to contradict the present state of rainfall in Freetown where deforestation is quite apparent; yet, rainfall is increasing which makes the rainfall pattern quite unique in this country. A recent study has reported that that deforestation affects the onset of rainfall in Brazil [19], but despite difference in the geography between this study and the referred study, it is true that deforestation alter the dynamics of the hydrological processes. Such observable pattern should warrant further investigation into the state of rainfall pattern in this country since no systematic pattern of precipitation is now observed.

Sierra Leone has an unviable position of one of the top countries most at risk to climate change primarily due to widespread deforestation in and around Freetown according to a report carried by Cable News Network (CNN). <http://edition.cnn.com/2013/10/29/world/climate-change-vulnerability-index/>. Such change in the land cover strongly influence surface runoff which now affects thousands of people living in low lying areas of the city. For instance, the flooding aftermath in 2012 due to the heavy torrential downpour resulted in cholera outbreak that killed more than 250 people within a short spell during the rainy season, and this alerted the Government of Sierra Leone to declare an emergency for the cholera outbreak. But with the increasing trend of rainfall, there is the tendency that rainfall over deforested areas may improve the regeneration of the forest, provided the affected land is lying fallow, thus providing positive feedback.

With apparent signs of variations in the climate of this country, it is imperative that scientific studies be undertaken at national and regional levels to provide society with accurate information on the rainfall and other meteorological variables so that better policies are put in place to address climate variability. Such investigation should include the dates of rainfall onset and cessation as well as the length of rainy season. Again, such anomalies in our climate would also have implications for the government of Sierra Leone ‘*Agenda for Prosperity*’ for which one its element is to increase agricultural output. At a period when the world is grappled with various environmental problems including global warming, ozone depletion, acid rain, recurrent droughts and major flood episodes, any effort at

finding scientific explanations to these and other problems is considered significant as the environmental, social and economic cost of climatic variability is bound to be enormous from the standpoint of society and human activity.

Conclusion

Results from this preliminary study has shown that rainfall in Freetown has changed over the years around the mean and this change has affected inter annual rainfall pattern over the decades. A combination of anthropogenic induced and meteorological factors has been ascribed to the observed pattern. At a time when there are signs of increasing rainfall in Freetown, there is the need for the government of Sierra Leone to seek risk tradeoff between increased combustion activities that produces CCN which on one hand would impact human health and reforestation programmes (enhancing rainfall) along mountainous areas of the city. We strongly recommend regular periodic analysis of the onset and cessation of rain as this would also serve as an indicator of climate variability which could have implications for the agricultural and water resource sectors.

Acknowledgements

We are grateful to the employees of the Forecasting unit of the Sierra Leone Meteorological Department for providing data for the stated period and their varied assistance in providing useful information in developing this report.

References

- [1] E.M. Mugalavai, E.C. Kipkorir, D. Raes, and M.S. Rao, Analysis of rainfall onset, cessation and length of growing season for western Kenya, *Agric. Fores. Meteor.*, 148, (2008) 1123-1135.
- [2] M.V.K. Sivakumar, Climate Change and Implications for Agriculture in Niger *Clim. Chan.*, 20, (1992)
- [3] O.F. Ati, C.J. Stigter, and E.O. Oladipo, A comparison of methods to determine the onset of the growing season in northern Nigeria, *Int. J. Climat.*, 22, (2002) 731-742.
- [4] D. Raes, A. Sithole, A. Makarau, and J. Milford, Evaluation of first planting dates recommended by criteria currently used in Zimbabwe, *Agric. Fores. Meteor.*, 125, (2004) 177-185
- [5] E.C. Kipkorir, D. Raes, R.J. Bargerei, and E.M. Mugalavai, Evaluation of two risk assessment methods for sowing maize in Kenya *Agric. Fores. Meteor.* , 144, (2007) 193-199.
- [6] P. Camberlin and M. Diop Application of daily rainfall principal component analysis to the assessment of the rainy season characteristics in Senegal, *Climat. Res*, 23, (2003) 159–169.
- [7] F.Y. Logah, E. Obuobie, D. Ofori, and K. Kankam-Yeboah, Analysis of Rainfall Variability in Ghana, *Int. J. Latest Res. Engin. Comput.*, 1, (2013) 1-8.
- [8] I.J. Ekpoh and E. Nsa, Extreme Climatic Variability in North-western Nigeria: An Analysis of Rainfall Trends and Patterns, *J. Geog. Geolog*, 3, (2011) 51-62.
- [9] S.B. Traoré, F. Reyniers, M. Vaksman, B. Koné, A. Sidibé, *et al.*, Adaptation à la sécheresse des écotypes locaux de sorghos du Mali *Sécheresse*, 11, (2000) 227-237.
- [10] C. Houndenou and K. Hernandez, Climate of the Sahel 1961-1990, *Secheresse*, 9, (1998) 23-34.
- [11] P. Tarawali, Diagnostic Analysis of Climate Change and Disaster Management in Relation to the PRSP III in Sierra Leone, UNDP-SL, (2012)
- [12] D. Rosenfeld, U. Lohmann, G.B. Raga, C.D. O'Dowd, M. Kulmala, *et al.*, Flood or Drought: How Do Aerosols Affect Precipitation?, *Sci*, 321, (2011) 1309-1313.
- [13] M. Jin and J.M. Shepherd, Aerosol relationships to warm season clouds and rainfall at monthly scales over east China: Urban land versus ocean,, *J. Geophys. Res* 113, (2008) D24S90, doi:10.1029/2008JD010276,.

- [14] Q. Zhang, J. Quan, X. Tie, M. Huang, and X. Ma, Impact Aerosol Particles on Cloud Formation: Aircraft Measurements in Beijing, China, *Atmos Environ*, 45, (2011) 665-672.
- [15] E.T. Taylor and S. Nakai, Monitoring the levels of toxic air pollutants in the ambient air of Freetown, Sierra Leone, *African Journal of Environmental Science and Technology*, 6, (2012) 283-292.
- [16] P.G. Munro, Deforestation: constructing problems and solutions on Sierra Leone's Freetown Peninsula *Journal of Political Ecology* 16, (2009) 104-122.
- [17] F.A.O. (FAO), State of the world's forests, technical report, U. N., Rome, (2009)
- [18] L. Garcia-Carreras and D.J. Parker, How does local tropical deforestation affect rainfall *Geophysical Research Letters*, 38, (2011) L19802.
- [19] N. Butt, P. Afonso de Oliveira, and M. Marcos Heil Costa, Evidence that deforestation affects the onset of the rainy season in Rondonia, Brazil, *Journal of Geophysical Research*, 116, (2011) D11120