

Analysis of Precipitation and Temperature Variability over Central Africa (1901-2015)

Yaw A. Twumasi^{1*}, Edmund C. Merem², John B. Namwamba¹, Tomas Ayala-Silva³, Kamran Abdollahi¹, Ronald Okwemba¹, Onyumba E. Ben Lukongo⁴, Caroline O. Akinrinwoye¹, Joshua Tate¹, Kellyn La Cour-Conant¹

¹Department of Urban Forestry and Natural Resources, Southern University and A&M College, Louisiana, USA

²Department of Urban and Regional Planning, Jackson State University, Jackson, Mississippi, USA

³USDA-ARS Tropical Agriculture Research Station, Mayaguez, Puerto Rico

⁴Department of Public Policy, Southern University and A&M College, Nelson Mandela College of Government and Social Sciences, Baton Rouge, Louisiana, USA

Email: *yaw.twumasi@subr.edu, *yaw.twumasi@gmail.com

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Abstract

Africa is already experiencing the impact of climate change. Some of the manifestations of climate change in Africa are, changing weather patterns resulting in, flooding and drought. Temperature change has impacted health, livelihoods, productivity of food, availability of water, and state of security. This study examines the long-term climate variations in Central African Countries (Gabon, Cameroon, Republic of Congo, Central Africa Republic, Chad and Democratic Republic of Congo) for the period 1901 to 2015, and then investigates the possible influence of increases in greenhouse gas concentrations. To investigate climate patterns and trends in the Central African Countries, precipitation and temperature were analyzed on annual time scales using data collected from the World Bank Group Climate Change Knowledge Portal. Data was further aggregated using annual average blocks of 10 years. Linear and polynomial regression was performed. Also, linear time series slopes were analyzed to investigate the spatial and temporal trends of climate variability in Central African countries. Results of the analyses indicated that the mean annual temperature and precipitation records in some of the Central African Countries had both warming and cooling trends over the study period from 1901 to 2015. For example, differences between the maximum and the minimum rainfall data for Democratic Republic of Congo, Cameroon and Gabon were 13 mm, 13 mm and 11.1 mm, which corresponded to 11.04%, 10.03% and 10.44% respectively. The study also found the temperature of Chad to have significantly risen from 1901 to 2015 by almost 20%, while its rainfall's variation was limited. Although the variation in rainfall in Chad was not dramatic, the temperature per 10 year rose by almost 20%. Chad's tem-

perature rose according to a cubic model from about 24.5°C to just below 27°C during the period 1901-1940. This was followed by a brief drop between 1940 and 1960. From 1960 to 2015 it rose according to the model to almost 28°C. By 2040 the temperature is expected to reach about 29.5°C if this trend continues. Gabon was found to be the wettest country in Central Africa. Between 1901 and 1960, its average rainfall rose from about 144 mm to a maximum of approximately 160 mm. It had a general average rainfall/10 year's increase from 1901 to 2015. The paper concludes by outlining policy recommendations in the form of improving national and regional environmental policies and regulations in the region, community involvement in decision making processes both at local and the national levels so as to contribute their input in the daily management of the forest resources, poverty alleviation in the region as well as building regional information system (RIS) incorporating Geographic Information System (GIS), remote sensing and other environmental and socio-economic data to help reduce anthropogenic emissions of greenhouse gases.

Keywords

Temperature, Rainfall, Climate Variability, Linear and Polynomial Regression, Central African Countries

1. Introduction

Climate is among important drivers of ecosystems' health, their compositions and other earth systems. Rainfall, atmospheric pressure, temperature and humidity are among the variables that control weather and climate respectively. Climate describes statistical variations of components of weather over time spanning from months to many centuries [1]. In the last two decades, there have been global concerns about the degradation of the world's ecosystems because of its attendant impact on greenhouse gases. The loss of biodiversity fueled by anthropogenic influences has been attributed in part to increased levels of greenhouse gases [2] [3] [4] [5] [6]. These changes in greenhouse gases and aerosols, taken together, are projected to lead to regional and global changes in temperature, precipitation, and other climate variables—resulting in global changes in soil moisture, an increase in global mean sea level, and prospects for more severe extreme high-temperature events, floods, and droughts in some places [5] [7]-[12]. Climate variations in temperatures and precipitations have been examined in different regions of the world over recent decades e.g. [13] [14] [15] [16] [17]. A study by Rosenbluth *et al.* [18] in Chile and Argentina reported variations in temperature due to influence of El Niño, Southern Oscillation on surface temperature along the Pacific South American coast 18°S to 53°S. Whitfield *et al.* [19] analyzed monthly temperature and precipitation time series for several hundred weather stations across Canada. Results showed variations in temperature and precipitation at different temporal and spatial scales. They further con-

cluded that, differences observed in temperature and precipitation could have been the result of variations in atmospheric circulations.

Global changes especially warming could impact regional climates, especially rainfall patterns in the long-term. Local activities such as modification of land cover and disruption of local and regional hydrology could also impact climates [20]. Among the physical parameters of climate, temperature and rainfall play roles of paramount importance [21] since conditions of the environment in different places of regions impacting agricultural productivity depend on them [22]). The warming earth alters temperature, rainfall and other patterns of weather and climate. This poses threats to human health, plant and animal lives respectively. This paper examines rainfall and temperature data in central African countries in order to determine existing patterns in variation of the data.

2. Methodology

2.1. The Study Area

Central Africa is a region of the African continent comprising of Angola, Burundi, Cameroon, the Central African Republic, Chad, the Democratic Republic of the Congo, the Republic of the Congo, Equatorial Guinea, Gabon, Rwanda, and São Tomé and Príncipe. This study focused on data from Democratic Republic of Congo (DRC), Republic of Congo, Cameroon, Chad and Gabon (Figure 1). The area is home to the world’s natural rainforests. As the region embarks

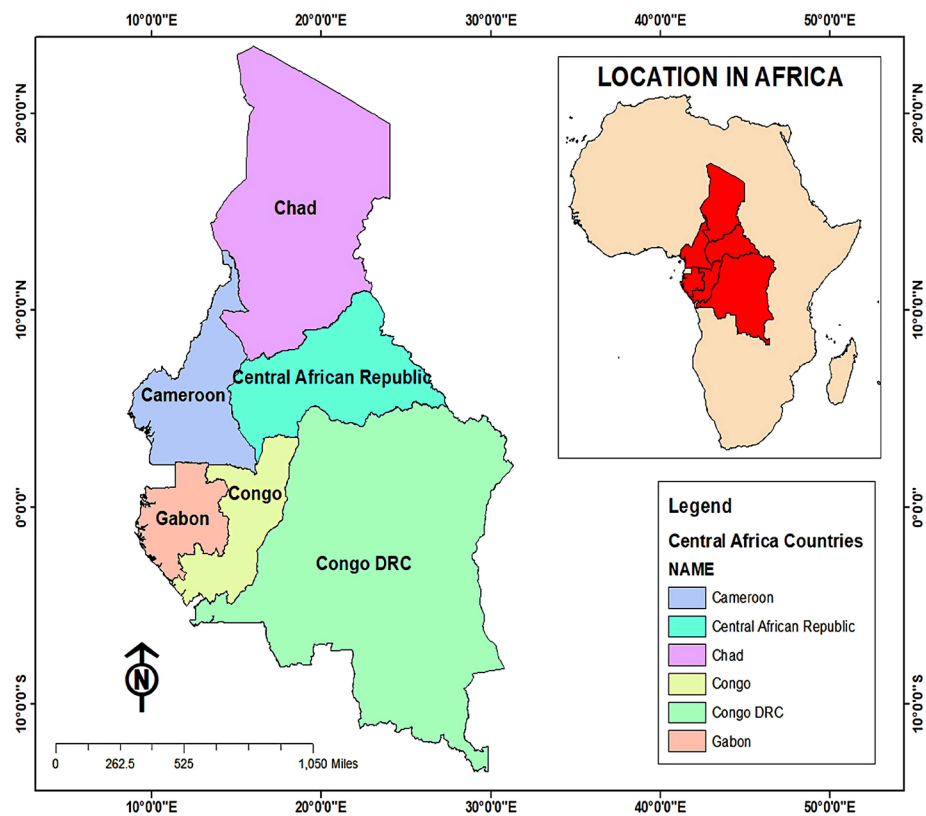


Figure 1. The study area.

upon an unprecedented phase of economic expansion, it faces several environmental challenges fueled partly by the pressures caused by human activities through economic activities, such as housing development, and road construction for transportation, economic development and demographic changes. In the last few decades, the region has been experiencing increasing resources degradation, fueling climate change [23]. Human activities inside these countries, for example, deforestation and degradation of forest resources, large scale and illegal mining, urbanization, slash and burn agriculture, resulting from shifting cultivation and uncontrolled exploitation to satisfy the needs of both the local and nonlocal populations are some of the major issues confronting the region. Rapidly growing population and poverty are stretching the resources of the basin beyond its carrying capacity.

2.2. Data Acquisition and Processing

For this study, temporal analysis of rainfall data from, the Democratic Republic of Congo, Cameroun, Gabon, Republic of Congo, Central African Republic and Chad were used. Rainfall and temperature data sets of 1950-2015 for the stated countries were downloaded from World Bank Group Climate Change Knowledge Portal for Development Practitioners and Policy Makers [24]. Before modeling, rainfall and temperature trends for each country, tables for 10-year blocks were made. **Table 1** illustrates the data used to compute the average monthly rainfall for the years 1911 to 1920, which is shown as 124.44 mm in the table. All the rainfall data collected from January 1911 to December 1920 was summed up and divided by the total number of months, yielding rainfall per month per 10 years. Microsoft Excel spread sheet was used to compute the averages. This procedure was used to compute all entries in **Table 2**, for Democratic Republic of Congo. The same procedure was also carried out for the other central African countries to yield data illustrated in **Table 3** and **Table 4** for Cameroun and Gabon respectively.

Table 1. Rainfall data mm/10 years table (1911-1920).

Month	Rainfall	Year	Month	Rainfall	Year	Month	Rainfall	Year	Month	Rainfall	Year
January	110.3	1911	June	42.2	1912	December	140	1914	May	122.9	1916
February	138.7	1911	July	55.2	1912	January	103.8	1915	June	63.1	1916
March	157	1911	August	80.4	1912	February	110.8	1915	July	41	1916
April	141.9	1911	September	141.1	1912	March	153.5	1915	August	84.4	1916
May	111	1911	October	145.8	1912	September	135	1916	February	104.1	1918
June	59.5	1911	November	191.9	1912	October	177.9	1916	March	175.1	1918
July	62.1	1911	December	142.1	1912	November	189.2	1916	April	156.6	1918
August	77.6	1911	January	112.2	1913	December	171.6	1916	May	92.9	1918
September	137.7	1911	February	126.4	1913	January	153.3	1917	June	68.8	1918
October	177	1911	March	148.4	1913	February	143.8	1917	July	60.4	1918

Continued

November	187.5	1911	April	147.5	1913	March	154.9	1917	August	85.7	1918
December	160.6	1911	May	115.4	1913	April	155.8	1917	September	123.2	1918
January	128.2	1912	June	64.4	1913	May	123.5	1917	October	146.2	1918
February	148.6	1912	July	45.4	1913	June	58.7	1917	November	170.3	1918
March	144.7	1912	August	68.2	1913	July	40	1917	December	191.2	1918
April	152.2	1912	September	86	1913	August	93.9	1917	January	184	1919
May	118.8	1912	October	174.1	1913	September	141.3	1917	February	145.5	1919
November	131	1913	April	135	1915	October	180.1	1917	March	148.4	1919
December	109.1	1913	May	91	1915	November	137.9	1917	April	129.5	1919
January	124.8	1914	June	70.3	1915	December	134.2	1917	May	98.3	1919
February	128.2	1914	July	37.4	1915	January	93.2	1918	June	93.7	1919
March	179	1914	August	75.6	1915	July	82.3	1919	April	140.7	1920
April	157.3	1914	September	160.4	1915	August	117.2	1919	May	135.9	1920
May	107.6	1914	October	134.7	1915	September	101.9	1919	June	65.1	1920
June	71.6	1914	November	159.8	1915	October	148.1	1919	July	69.6	1920
July	67.7	1914	December	177.2	1915	November	192.5	1919	August	58.6	1920
August	86.4	1914	January	116.7	1916	December	168.9	1919	September	116.2	1920
September	134.4	1914	February	130.1	1916	January	116.3	1920	October	172.6	1920
October	193.2	1914	March	148.9	1916	February	112.1	1920	November	162.9	1920
November	174.3	1914	April	168.6	1916	March	166.9	1920	December	157	1920
Average rainfall, mm/month										124.4	

Table 2. Average monthly rainfall mm/10 years for Democratic Republic of Congo (DRC).

Average rainfall mm/10 years (Democratic Republic of Congo)	
Years after 1900	Average rainfall (mm)
1901	122.8631
1910	126.487
1920	124.44
1930	124.3271
1940	126.6208
1950	126.0523
1960	128.9018
1970	132.4034
1980	125.5405
1990	127.811
2000	119.2098
2010	124.8244
2015	127.3143

Table 3. Average monthly rainfall mm/10 years for Cameroun.

Year	Average rain/10 years
1901	137.8247
1910	137.8247
1920	137.0419
1930	135.0912
1940	136.6843
1950	134.2571
1960	133.1015
1970	140.1571
1980	139.6232
1990	133.0645
2000	127.3796
2010	134.3287
2015	130.0457

Table 4. Average monthly rainfall mm/10 years for Gabon.

Year	Average rain/10 years
1901	144.4524
1910	146.2408
1920	144.9641
1930	150.4393
1940	148.9023
1950	152.9573
1960	159.5338
1970	156.1968
1980	150.1271
1990	150.6118
2000	152.3903
2010	151.0454
2015	155.4274

To develop models that identify trends in rainfall and temperature data sets, aggregation of data using batches of 10 years was adopted for all the countries. In the modelling of the variations between variables in atmospheric data, regression was used.

The models for average rainfall and temperature based on data sets of 10 consecutive years were modeled based on the following respective formulations.

$$\text{Rainfall, } R \propto f(t)$$

For cubic model,

$$R = A_{n+1}t^n + A_n t^{n-1} + A_{n-1} + t^{n-2} + A_{n-2} \quad (1)$$

For quadratic model,

$$R = A_{n+1}t^n + A_n t^{n-1} + A_{n-1} + t^{n-2} + A_{n-2} \quad (2)$$

For linear model,

$$R = At + B \quad (3)$$

where, R is the average rainfall based on 10 consecutive years in mm/year, n is the polynomial index and t is time in years. A_1 , A_2 , A_3 and B are constants.

$$\text{Temperature } T \propto f(t)$$

For cubic model,

$$T = A_{n+1}t^n + A_n t^{n-1} + A_{n-1} + t^{n-2} + A_{n-2} \quad (1)$$

For quadratic model,

$$T = A_{n+1}t^n + A_n t^{n-1} + A_{n-1} + t^{n-2} + A_{n-2} \quad (2)$$

where, T is the average temperature based on 10 consecutive years in °C/year, n is the polynomial index and t is time in years. A_1 , A_2 and A_3 are constants.

Statistical software (SPSS, Microsoft Excel data analysis toolkit, etc.) was used to fit data and build models. The strength of model developed was based on the magnitude of the coefficients of correlations between variables (R square), which ranged from 0 to 1.0 (0% - 100%).

A model was accepted if the corresponding coefficient of correlation was close to 100%. Linear and curvilinear modellings were applied depending on the correlations between data pairs, which attempts to develop single models for data sets spanning from 1901 to 2015 yielded models of low coefficients of correlations for most data sets. To develop models that were more representative of the data sets, illustrating the rises and falls in environmental data, data aggregates from time spans shorter than the entire data collection range of time (1901-2015) were used in modeling. Modeling for rainfall trends was carried out for, the Democratic Republic of Congo (DRC), Gabon and Cameroun since the difference between their maxima and minima rainfall data was at least 10%. Only Chad had a percentage change of temperature higher than 15%. Hence temperature change was only analyzed for Chad. The modeling processes and corresponding results for each of the countries are discussed as follows.

3. Results and Discussion

Democratic Republic of Congo (DRC)

Rainfall

The data used in modeling rainfall for the Democratic Republic of Congo (DRC) is presented in **Table 2**.

The difference between the maximum and the minimum rainfall data was 13 mm. The percentage rise from the minimum to maximum temperature was

$((132.4 - 119.2)/119.2) \times 100 = 11.04\%$. Regression analysis was used to model the Democratic Republic of Congo's average monthly rainfall data per consecutive 10 years versus years. The data from 1901 to 1940 was fitted into a third order polynomial equation. The general average rainfall trend from 1901 to 1940 is represented by a gradual rise from about 123 mm in 1901 to a maximum quantity of 126 mm in 1910 (Figure 2). It then dropped gradually to a minimum value of 124 mm in 1930. It then gradually rose to 126.5 mm in 1940. The model is represented by the equation illustrated in Figure 2. This equation explains about 91% of the variation in average rainfall data for the specified span of time.

A polynomial function of order 3 was used to model rainfall data from 1940 to 1980 by curve fitting. The equation and the curve are given and illustrated in Figure 3.

The average rainfall/10 years dropped from about 127 mm in 1940 to a local minimum of 125 mm in 1945. It then rose to a local maximum of about 132 mm in 1970, and then gradually dropped to a value between 125 mm and 126 mm in

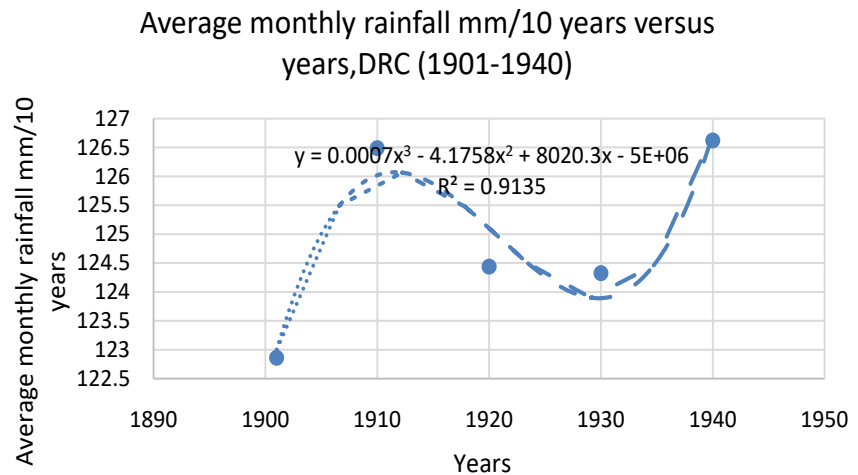


Figure 2. Variation of average monthly rainfall mm/10 years' aggregates, DRC (1901-1940).

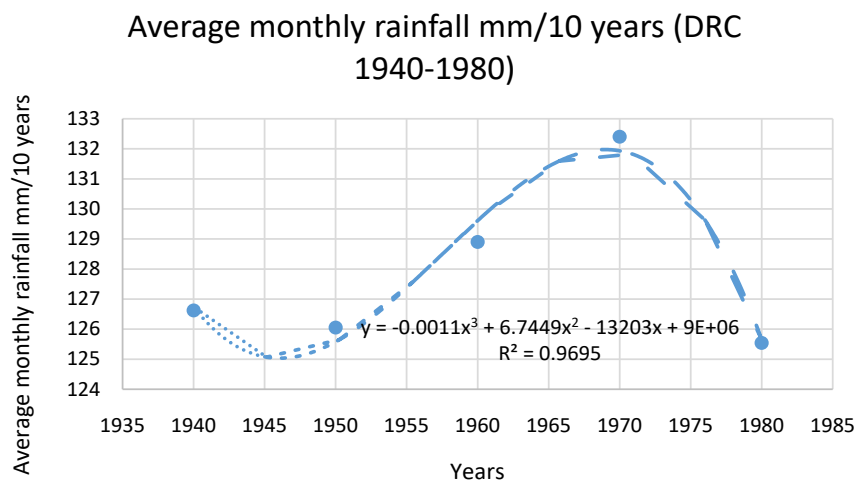


Figure 3. Variation of average monthly rainfall mm/10 years' aggregates, DRC (1940-1980).

1980 (Figure 3). This equation explains about 97% of the variation in average rainfall/10 data for the specified span of time ($R^2 = 0.9605$).

The average rainfall data/10 consecutive years for the time span 1980-2015 was fitted into a third order polynomial equation. The equation for the trend and the curve is illustrated in Figure 4. According to the model, the average rainfall per 10 years rose from an initial magnitude of approximately 126 mm in 1980, to approximately 128 mm in 1985. It then dropped gradually to a local minimum of about 120 mm in 2005. It then rose gradually to 128 mm by 2015. For this model, R squared is 0.688. Hence, the model explains or represents about 69% of the data. Stronger models for the data for 1980-2015 were developed by modeling data sets for 1980-2000 and 2000-2015 separately to yield the models illustrated in Figure 5 and Figure 6 respectively.

4. Cameroun

The difference between the maximum and the minimum rainfall data for Cameroun's data is 13 mm. Hence, the percentage rise from the minimum to maximum

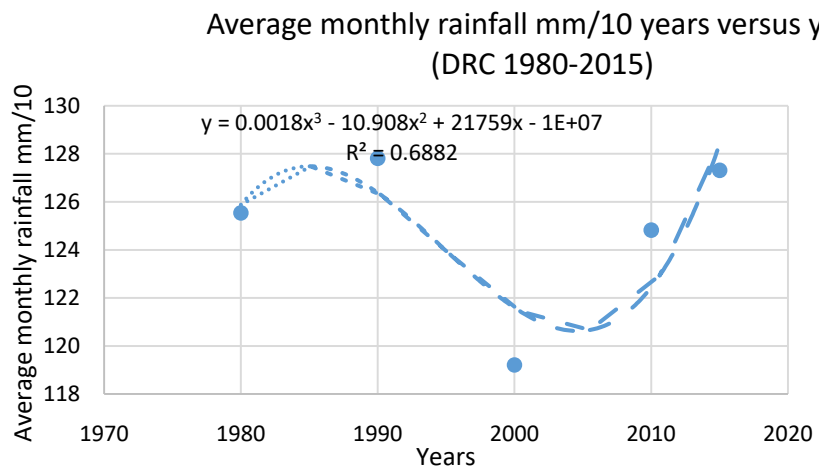


Figure 4. Variation of average monthly rainfall mm/10 years' aggregates, DRC (1980-2015).

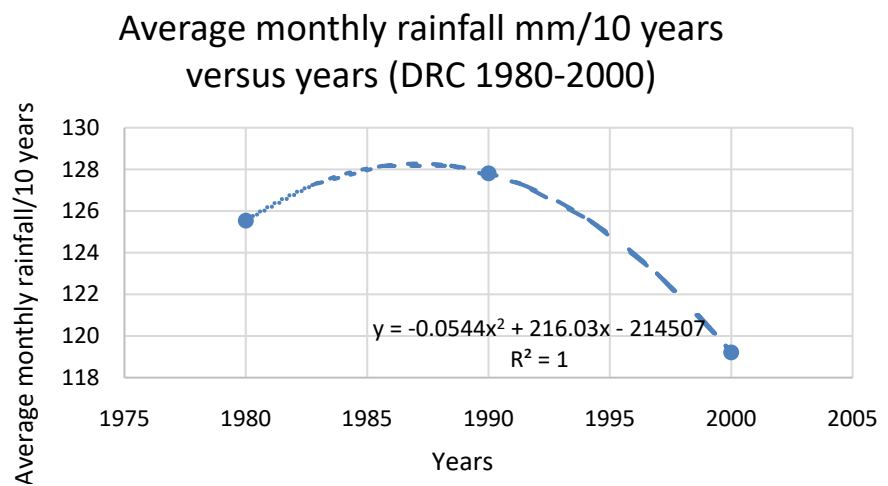


Figure 5. Variation of average rainfall, mm per 10 years' aggregates, DRC (1980-2000).

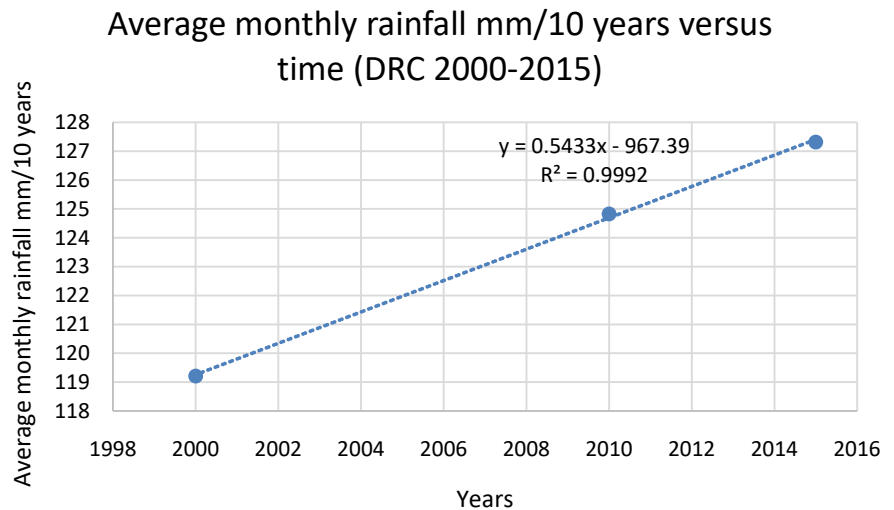


Figure 6. Variation of average rainfall per 10 years' aggregates, DRC (2000-2015).

temperature was $((140.157 - 127.38)/127.38) \times 100 = 10.03\%$. The data used in modeling rainfall Cameroun is presented in **Table 3**.

The mean rainfall data per 10 consecutive years was fitted to a cubic equation. The following model was developed. $y = -2E-05x^3 + 0.1287x^2 - 250.73x + 162992$ (**Figure 7**).

Where, y is the average rainfall based on every 10 consecutive years in mm/year and x is time in years.

This model suggested a decreasing trend for rainfall from 138 mm to 130 mm. R squared for the cubic model was 0.4038; hence, it represents or explains about 40% of the data.

Better models for this data were developed by fitting the data for 1901-1960 to a quadratic polynomial using Microsoft Excel curve fitting tool. The model had R squared equal to 0.8465. Hence, the model explains about 85% of the data (**Figure 8**).

The data for 1960-2015 was fitted to a third order polynomial model with R squared equal to 0.732 (**Figure 9**). Hence the model; explains about 73% of the data.

Stronger models for the data for 1980-2015 were developed by modeling the data for the time periods of 1980-2000 and 2000-2015. The corresponding models are illustrated in **Figure 10** and **Figure 11** respectively.

The model for the period 2000-2015 (**Figure 11**) had R squared equal to 1. Hence, it represented 100% of the variability in the data.

The model illustrates a rise from 127 mm to about 135mm in 2008, followed a drop to 130 mm by 2015. According to the model, Cameroun's average rainfall was expected to drop as years progressed beyond 2015.

5. Gabon

The difference between the maximum and the minimum rainfall data is 15 units. The data used in modeling rainfall Gabon is presented in **Table 4**.

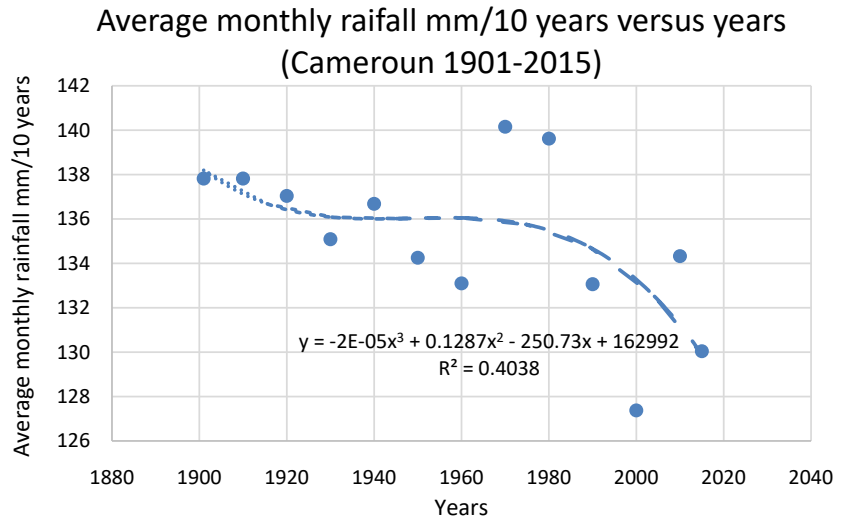


Figure 7. Variation of average rainfall mm/10 years' aggregates, Cameroun (1901-2015).

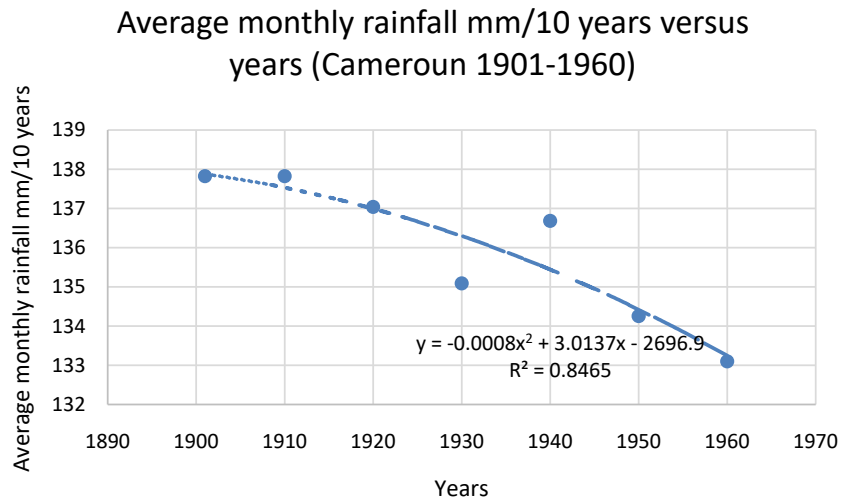


Figure 8. Variation of average rainfall mm/10 years' aggregates, Cameroun (1901-1960).

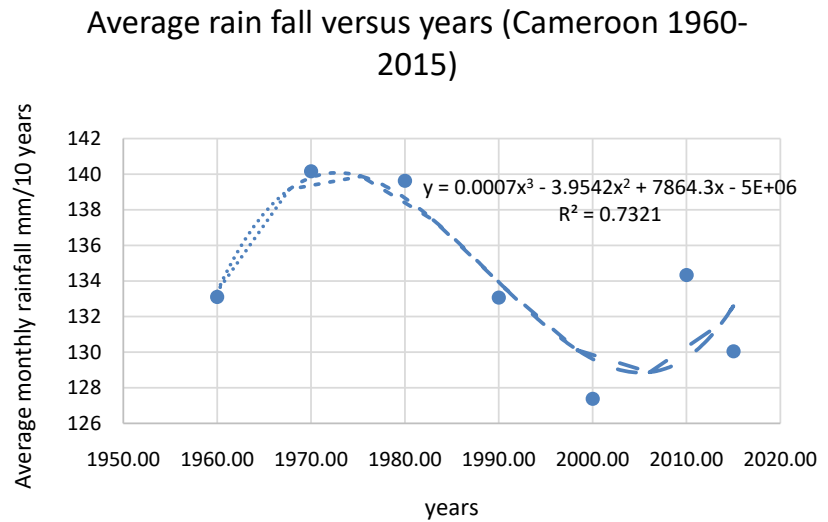


Figure 9. Variation of average rainfall mm/10 years' aggregates, Cameroon (1960-2015).

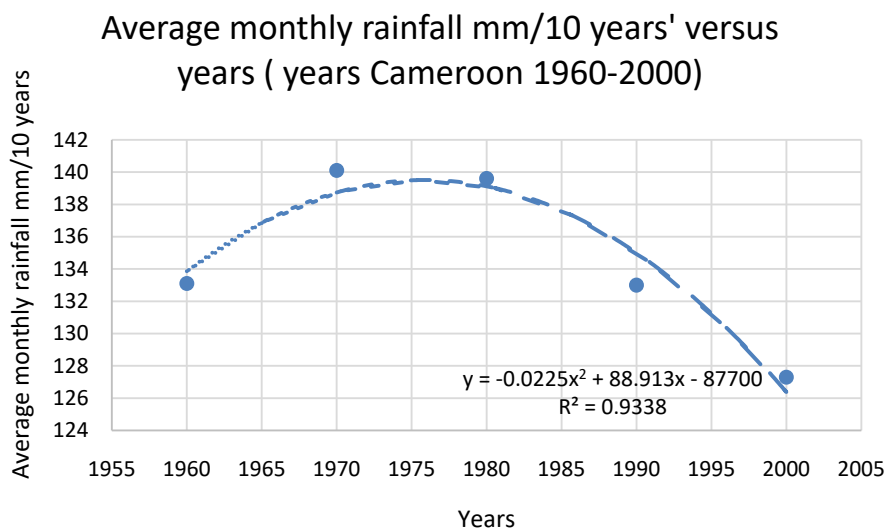


Figure 10. Variation of average rainfall mm/10 years' aggregates, Cameroun (1960-2000).

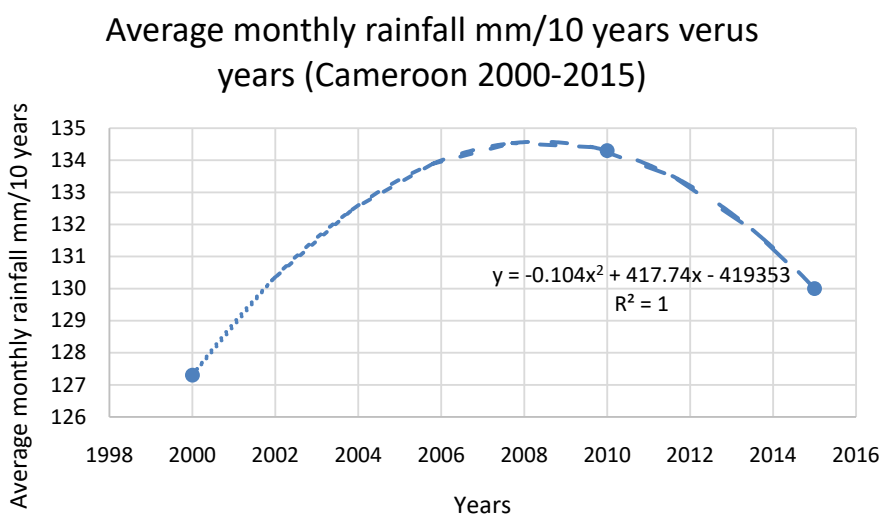


Figure 11. Variation of average rainfall mm/10 years' aggregates, Cameroun (2000-2015).

The data was fitted to a second order polynomial model using regression. Hence, the percentage increase from the minimum to the maximum temperature was $((155.5 - 144.4)/144.4) \times 100 = 10.44\%$. The rainfall data for Gabon from 1901-2015 follows a second order polynomial function with $R^2 = 0.5662$. The model explains about 56.6% of the variation. The model is represented as, $y = -0.0016x^2 + 6.4385x + 6222.3$. According to this model, the average rainfall per 10 years rose from about 144 mm in 1901 to approximately 154 mm in 1970 and then dropped gradually to 152 mm (Figure 12).

Better models for Gabon's average rainfall were developed by modeling the data piecewise. A quadratic model was developed for average the rainfall between, 1901 and 1960. A strong model with $R^2 = 0.9155$ was developed (Figure 13). The model is represented by the following equation: $y = 0.0044x^2 - 16.856x + 16,198$.

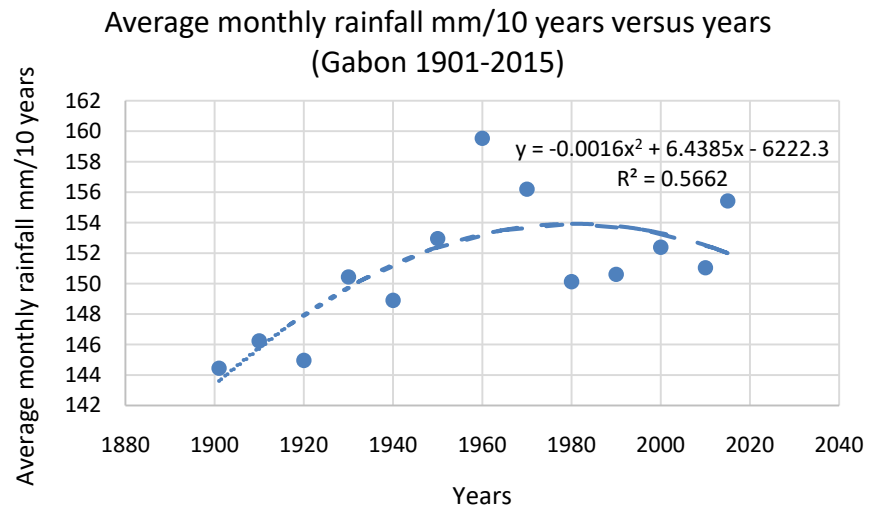


Figure 12. Second order polynomial model for average monthly rainfall mm/10 years’ aggregates for Gabon 2005-2015.

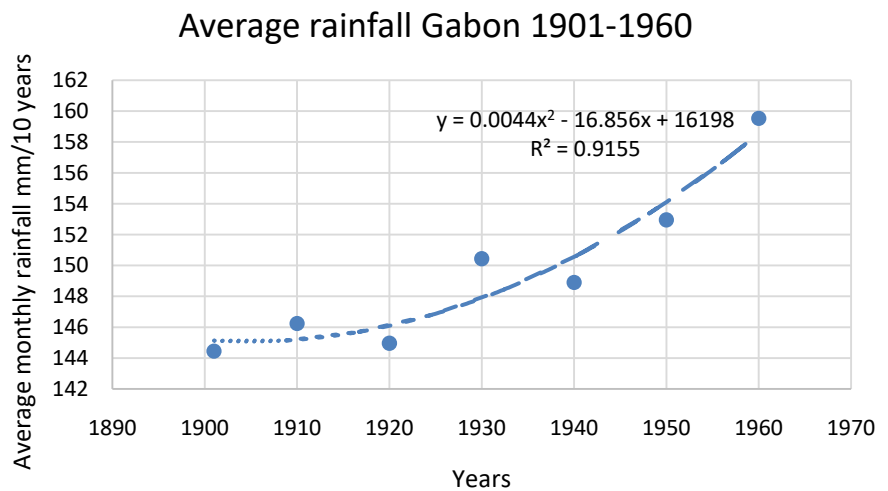


Figure 13. Second order polynomial model for average monthly rainfall mm/10 years aggregates for Gabon 1900-1960.

A quadratic model was developed for rainfall data for the period 1960-2015. The model is presented as follows. $y = 0.0087x^2 - 34.763x + 34791$, with $R^2 = 0.8493$. The model explains about 85% of the average rainfall/10 year’s variation during the period 1960-2015 (Figure 14).

Where, y is the average rainfall based on every 10 consecutive years in mm/year and x is time in years.

6. Chad Temperature

The difference between the maximum and the minimum average temperatures per ten-year data aggregates was 3.5°C (5.3 F), which corresponded to a percentage rise equal to $(4.5/24.5) = 18.36\%$.

The average monthly temperature for Chad per 10 years is presented in Table 5.

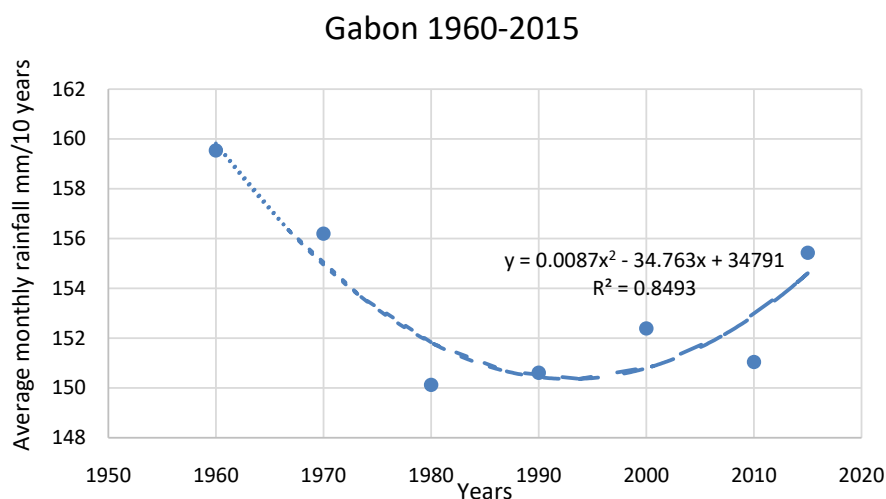


Figure 14. Second order polynomial model for average monthly rainfall mm/10 years aggregates for Gabon 1960-2015.

Table 5. Average monthly temperature °C /10 years for Chad.

Year	Average monthly temperature °C/10 years
1901	24.37034
1910	26.61626
1920	26.57028
1930	26.66089
1940	26.80198
1950	26.45233
1960	26.36165
1970	26.39722
1980	26.71711
1990	26.84742
2000	26.84741
2010	27.85025
2015	27.63414

A correlation analysis for the average temperatures per 10 years data and was run, using SPSS 20 software. The correlation between the average temperatures per 10 consecutive years was found to be statistically significant ($p = 0.006$), with coefficient of correlation being equal to 71% (**Table 6**).

Microsoft Excel software was used to fit a cubic model the variation between the data sets using regression. The model is given by the equation, $y = 1E-05x^3 - 0.0725x^2 + 142.07x + 23.783 - 92,751$, $R^2 = 0.8016$ (**Figure 15**). Where, y is the average temperature based on 10 consecutive years in °C/year and t is time in years.

According to the model, the temperature rose from an initial approximate

Table 6. Correlation table for the mean temperature per consecutive 10 years versus years (Chad).

Correlations			
		Mean temperature	Years
Mean temperature	Pearson correlation	1	0.712**
	Sig. (2-tailed)		0.006
	N	13	13
Years	Pearson correlation	0.712**	1
	Sig. (2-tailed)	0.006	
	N	13	13

** . Correlation is significant at the 0.01 level (2-tailed).

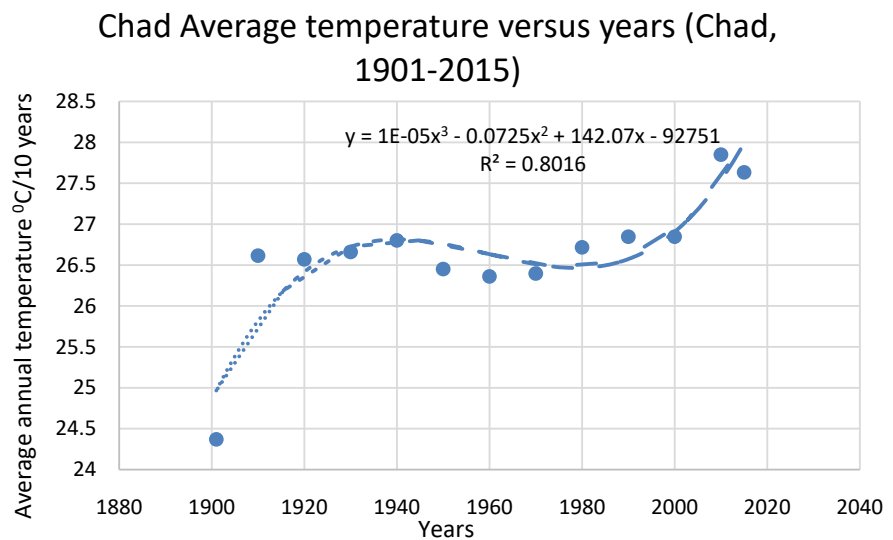


Figure 15. Variation of average monthly temperature/10 years for Chad (1901-2015).

value of just below 24.5°C in 1901 to almost 27°C in 1940. It then marginally dropped to about 26.5°C in 1980. During the period 1980-2015 it rose to approximately 28°C. Stronger models were developed for variation of the data through shorter time spans (1901-1950) and (1950-2015). The corresponding cubic and quadratic models had R squared (coefficients of determination) equal to, 0.907 and 0.901 respectively. These models are illustrated in **Figure 16** and **Figure 17** respectively

Between 1995 and 2015 the average temperature of chad rose sharply. According to the models illustrated in Figure 13 and Figure 15, the average temperature of Chad will likely rise significantly over future decades and possibly impact the environment negatively.

If the temperature continues to rise according to the model, Microsoft Excel statistical tool kit can be used to model its value by 1940 by entering 15 years in the forecasting tab. The temperature for the period 2015-2040 is illustrated in the following graph (**Figure 18**). The temperature by 2040 is expected to be 24.5°C.

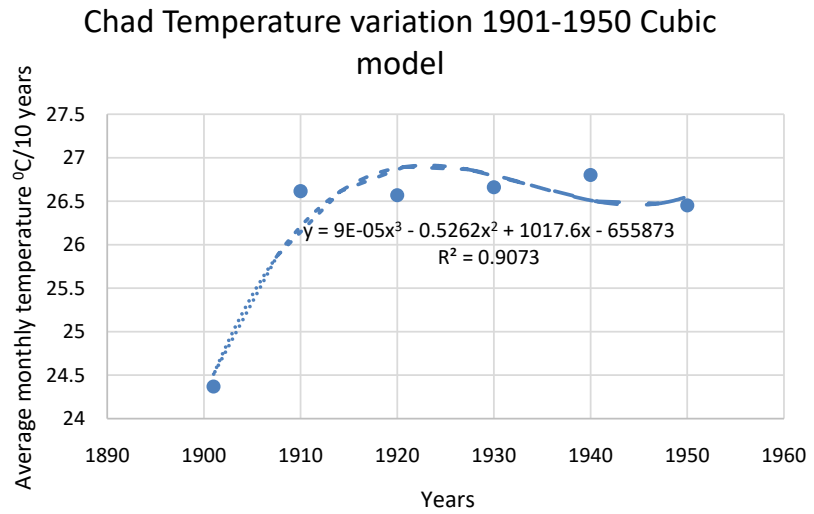


Figure 16. Chad variation of average monthly temperature/10 years for Chad (1901-1950).

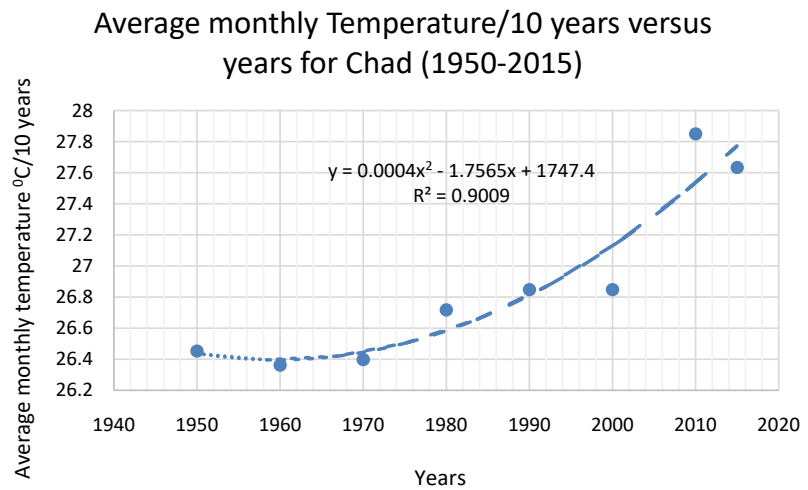


Figure 17. Chad variation of average monthly temperature/10 years for Chad (1950-2015).

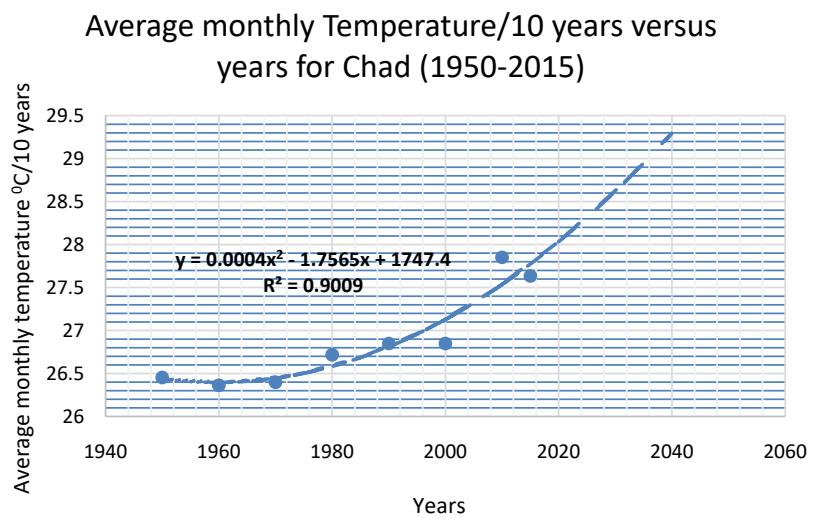


Figure 18. Chad modeling temperature for the period 2015-2040.

The average rainfall of the Democratic Republic of Congo had a first general trend of rising, followed by a decrease to a minimum of about 123 mm. It then rose gradually to about 127 mm. The average rainfall for Cameroun dropped from about 138 mm in 1905 to 133 mm in 1960. It then rose to about 140 mm in 1980, followed by a drop to about 139mm. In general, Cameroun's rainfall data tended to decrease from 1905 to 2015 (**Figure 6**). The average rainfall of Gabon increased to a maximum of approximately 160 mm according to the model illustrated in **Figure 12** and then dropped to a minimum of about 150mm according to the model illustrated in **Figure 13**. However, in general, the rainfall increased (**Figure 11**). The temperature of Chad was observed to rise from about 24.5°C to about 28°C from 1900 to 2015 according to a cubic model (**Figure 14**). Variability in climate and anthropogenic activities have impacted Lake Chad, with the former accounting for about 34% to 45% during the time span 1972 to 2013 [25].

7. Policy Recommendations and Conclusion

Anthropogenic activities such as clearing of land for agriculture, industry, slash-and-burn agriculture and other human activities in the region have an impact on the concentration of greenhouse gases which ultimately leads to global warming. Perhaps, introduction of a policy which focuses on improving national and regional environmental policies and regulations in the region would go a long way to minimize some of the anthropogenic activities especially deforestation which are very rampant in the region [26]. Similarly, since most of these forest resources are spread out in the villages and rural areas, communities should be involved in decision making process both at local, regional and the national level, so as to contribute their input in the daily management of the forest and other natural resources. Any policy directed towards managing these forest resources from the top hierarchy level without community involvement is likely to fail. Local communities have played prominent roles in addressing pressing environmental issues so as to improve ecosystems. Hence, community based environmental protection should be included in environmental protection policies [27]. Also, in most African countries, environmental degradation is driven by poverty. Policies that deal with addressing poverty and raising the income levels as well as increasing the welfare of village communities in an eco-friendly manner will help alleviate environmental degradation in the region [28]. To reduce greenhouse gas emissions and forest management, there is the need to design and build a comprehensive Regional Information Systems (RIS) in the form of periodic inventorying, monitoring and evaluation with full support of the governments in the study area. RIS would entail combining remote sensing and geographic information system (GIS) data, climate data, field survey data, land use, forest cover and forest cover change into one system. Developing such a system will offer the decision makers access to the appropriate temporal-spatial data for monitoring the pressures mounted on the areas' ecosystems and socio-economic needs. Such a tool could act as an effective decision

support system in order to keep development in harmony with environmental sustainability, efficient land use planning and management of protected areas [29] [30].

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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