Research Article

Statistical Analysis of Rainfall Trend for Volta Region in Ghana

M. Nyatuame, V. Owusu-Gyimah, and F. Ampiaaw

Agricultural Engineering Department, Ho Polytechnic, P.O. Box 217, Volta Region, Ghana

Correspondence should be addressed to M. Nyatuame; doga_nyatuame@yahoo.com

Received 27 June 2014; Accepted 6 September 2014; Published 19 October 2014

Academic Editor: Panagiotis Nastos

Copyright © 2014 M. Nyatuame et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Climate change is global in nature, but potential changes are not expected to be globally uniform; rather, there may be dramatic regional differences. Considerable effort should be invested to understand climate change at the regional level. The study was conducted to establish the rainfall trends in Volta Region and also to provide the evidence of climate change by analyzing available rainfall record for 30-year period of 1981 to 2011. Records of monthly and yearly rainfall were obtained from the headquarters of Ghana Meteorological Department, Accra, for analysis. The region was grouped into three zones characteristic of the whole country, namely, coastal zone, middle zone, and northern zone, respectively. Graphs were constructed to illustrate the changing trends within the months and years of the zones. Statistical analysis (i.e., LSD, ANOVA) was performed to assess any significant difference among the three zones and within the months and years under study. Significant differences were observed among the three zones. Northern zone recorded the highest precipitation followed by the middle zone and lastly the coastal zone. However the rainfall trends within the aforementioned zones were oscillatory. The highest annual mean rainfall was 202.6 mm and the lowest was 29.9 mm. Linear regression analysis revealed upward and downward trend in the data in some months and years in the mentioned zones but statistically insignificant.

1. Introduction

Water is one of our most valuable natural resources and vital to all forms of life. Water is also used for transportation, is source of power, and serves many other useful purposes for domestic consumption, agriculture, and industry. The main important source of water in any area is rain. The amount or availability of water for various purposes is very much depending upon the amount of precipitation in that particular area. Excess or extended absence of rainfall will cause flooding and drought, respectively. Adler et al. [1] stated that precipitation information is essential for understanding the hydrologic balance on a global scale and for understanding the complex interactions among the components within the hydrologic cycle.

The availability of adequate freshwater of appropriate quality has become a limiting factor for development worldwide [2]. In arid and semiarid regions of the world, water scarcity and low per capita water allocation were always a dominant challenge. The situation has further exacerbated due to increase in population and the associated expansion

of urbanization and economic activities, all of which demand more water and thus impose a tremendous pressure on the inadequate water resources.

Rainfall is the meteorological phenomenon that has the greatest impact on human activities and the most important environmental factor limiting the development of the semi-arid regions [3]. Understanding rainfall variability is essential to optimally manage the scarce water resources that are under continuous stress due to the increasing water demands, increase in population, and the economic development [4].

There are many aspects of water resources management including the optimal water allocation, quality assessment and preservation, and prediction of future water demands to strategize water utilization, planning, and decision making. As a preliminary step, these management aspects and others necessitate the characterization of the water sources in the area of interest. One of the established methods to carry out this assessment is through the statistical analysis of the spatial and temporal variability of rainfall. In regions that have heavy agricultural areas and undergo dense activities, water availability and shortage challenges are further exacerbated.

In Ghana, many watersheds are under extreme stresses due to the climate changes and drought conditions that influence water availability in a negative manner when considering the increasing need to boost up the agricultural production rate [5].

While climate change is global in nature, potential changes are not expected to be globally uniform; rather, there may be dramatic regional differences. Considerable effort should be invested to understand climate change at the regional level. Volta Region is one of the ten regions in Ghana (Figure 1), and it is said to be a microcosm of Ghana. That is to say all the six ecological zones in Ghana are represented in Volta Region (Figure 2).

This situation has compelled the motivation for assessing the magnitude and variability of rainfall for Volta Region. Statistical analysis of rainfall records for long periods is essential to provide information about rainfall variability and to better manage the rain fed agricultural activities such that the impact of climate change as well as changes in land use can be realistically assessed.

This paper carries out a statistical analysis of the long-term rainfall data for the Volta Region. The major objective of this work is to statistically analyze the temporal variation in annual and monthly rainfall data of Volta Region. This analysis is essential to provide input data for a management system and to enable the development of optimal water allocation policies and management strategies to bridge the gap between water needs and obtainable water supply under possible drought conditions. On an annual scale, the analysis will help in the evaluation of the total water budget of the water resources in the area. Monthly rainfall analysis can be used in the determination of the crop water requirements. The paper is organized as follows. Description of Volta Region is presented followed by the annual and monthly rainfall statistical analysis. Time series of annual and monthly rainfall data were studied and annual trends were extracted and conclusions are furnished.

The Volta Region is located along the southern half of the eastern border of Ghana, which it shares with the Republic of Togo. Greater Accra, Eastern, and Brong Ahafo regions share boundaries with it on the west, on the north by the Northern Region, and on the south by the Gulf of Guinea. The region occupies an area of 20,570 square kilometres or 8.6 per cent of the total land area of Ghana [6].

The region has a length of about 500 kilometres, stretching from the south to the north. It encompasses most of the vegetation zones found in the country, that is, the coastal grassland and mangrove swamps, replete with sandy beaches, the Guinea savannah through moist semideciduous forests in the central highland areas to the undulating Sahel-savannah, and the mountainous wooded savannah in the north [6].

As in all other parts of the country, the Volta Region has a tropical climate, characterised by moderate temperatures, 21–32° Celsius (70–90°F), for most of the year. The region has two rainfall regimes in the year; the first is from March to July and the second is from mid-August to October. Rainfall figures, which vary greatly throughout the region, are highest in the central highland areas and in the forest zone; they are lowest in the Sahel-savannah zone in the north of the region.

FIGURE 1: Map of Ghana.

The maximum average annual rainfall figure is 2,103 mm and 1,168 mm, minimum. More than half of the land area of the region falls within the Volta River Basin, with the Volta Lake draining a substantial portion of the region [6]. The region's mountains form part of the Togo Range, which stretches from parts of the Ashanti and Eastern Regions into the Republic of Togo. The highest mountain in Ghana, Mount Afadjato (Avadzeto), located in the Hohoe District, is part of this range. This mountain, together with several picturesque physical features such as the Wli waterfalls, near Mountain Gemi (Amedzofe), and the monkey sanctuary in Tafi (Hohoe district) are some of the region's tourist attractions [6].

2. Materials and Methods

Monthly rainfall data were obtained from the Ghana Meteorological Department on Volta Region. Volta Region was used in the study because it represents the entire climatic scope of Ghana. The six ecological zones in Ghana are represented in the Volta Region, hence the saying that Volta Region is the microcosm of Ghana. The data obtained cover the period of 1981 to 2011 and the Volta Region was grouped into three zones, namely, coastal, middle, and northern zones, respectively. Statistical analyses were performed to assess any significant difference among the three zones and within the months and years under study on the data and graphs

Linear regression is one of the simplest methods to calculate the trend of data in time series. The equation of

linear regression line is given by $Y = a + bX$, where X is the independent variable and Y is the dependent variable. The slope line is b and a is the intercept (value of Y when $X = 0$). The slope of regression describes the trend whether positive or negative. In this study dependent variable Y is rainfall and independent variable X is year. Linear regression requires the assumption of normal distribution. In this study, the null hypothesis is that the slope of the line is zero or

there is no trend in the data. The significance of the slope is shown by the probability value (P value) of it. Microsoft Excel was used to calculate the lines and statistical values of linear regression analysis. The P value from the analysis is the test for the significant level $\alpha = 0.05$.

The value of R -square (R^2) or the square of the correlation from the regression analysis was used to show how strong the correlation and relationship between the variables X and Y are. The value is a fraction between 0.0 and 1.0. An R^2 value of 1.0 means that the correlation becomes strong and all points lie on a straight line. On the other hand, an R^2 value of 0.0 means that there is no correlation and no linear relationship between X and Y .

3. Results and Discussion

3.1. Hypothesis Testing

H_0 : there is no significant difference in the mean annual rainfall among the climatic zones in the Volta Region over the period of thirty years.

H_1 : there is significant difference in the mean annual rainfall among the climatic zones in the Volta Region over the period of thirty years.

Table 1 shows an ANOVA to determine whether significant difference existed in the mean annual rainfall among the three climatic zones in the region. The results indicated that the difference in annual rainfall among the zones was highly significant ($F = 42.55$, $P = 0.000$). The hypothesis that there is no significant difference in the mean annual rainfall among the climatic zones in the Volta Region over the period of thirty years is therefore rejected.

To determine which of the zones actually differed in terms of mean annual rainfall, the multiple mean comparisons were performed using LSD (the LSD was used because the ANOVA revealed that there were differences in the climatic zones). The results in Table 2 indicated that the mean difference in annual rainfall among the zones was highly significant, except that of northern and middle zones. Here the mean difference in annual rainfall observed over the period in the two zones was not statistically significant (mean diff. = 7.673 mm, $P = 0.157$).

From Figure 3 it is evident that the annual rainfall among the zones under consideration could best be described as oscillatory. The trend is not regular but irregular. However comparing the three zones, it can be observed that the middle zone trend is more regular than the rest. Additionally, the northern zone has the highest oscillatory trend of rainfall. The higher precipitation recorded in the northern zone generally could be attributed to the mountainous nature of the area, coupled with thick forests and also the Volta River which supply the bulk of the atmospheric moisture for precipitation. The low rainfall at coastal zone could be attributed to the vegetationless nature of the area. The loss of vegetation in these areas, compared to that of forest and mountainous areas, reduces natural cooling provided by evapotranspiration, the process through which intercepted radiation is utilized by plants, soils, and water bodies to

TABLE 1: Analysis of variance of mean annual rainfall among coastal, middle, and northern zones of Volta Region in Ghana from 1981 to 2011.

	Sum of squares	Df	Mean square	F	P value
Between groups	36877.748	2	18438.874	42.55	.000
Within groups	37699.022	87	433.322		
Total	74576.770	89			

$P \leq 0.001$.

FIGURE 3: Fluctuation of rainfall for the three zones (1981–2011).

convert water to water vapour [7]. This water vapour rises to the upper atmosphere, condenses, and eventually falls as rain. However, [8, 9] averred that since rainfall in the tropics is extremely variable in both space and time, identifying the precise cause of fluctuations remains problematic.

From Table 3, the year with the highest annual rainfall was 1991, which recorded an amount of 1298.1 mm with a corresponding highest mean value of 108.2 mm. The record indicated the standard deviation correlating the highest annual rainfall was 148.9 mm and the data was skewed right, meaning the rainfall distribution is flat. However, the maximum annual rainfall standard deviation occurred in 1997, with a value of 168.08 mm, meaning the rainfall was highly dispersed or there was inconsistency in the rainfall pattern in 1997, with the corresponding highest range value. This observation again was buttressed by the highest variance and coefficient of variation figures recorded, respectively. According to Dewar and Wallis [10], the variation of CV values indicates the existence of strong variability in the rainfall of the study area. Nonetheless the maximum monthly rainfall occurred in 1997 in June. In addition, the lowest annual rainfall occurred in 1992 with an amount of 359.2 mm and a corresponding annual mean value of 29.9 mm.

In Table 4, it can be inferred that the maximum annual rainfall of 1747.6 mm and the corresponding mean of 145.6 mm occurred in 1999 for the period under consideration. The minimum annual rainfall occurred in 1992 (808.1 mm) and the maximum annual standard deviation of

TABLE 2: LSD multiple comparisons of mean annual rainfall of the climatic zones in Volta Region from 1981 to 2011.

Zones	(J) zone	Mean difference ($I - J$)	P value	95% confidence interval	
				Lower bound	Upper bound
Northern zone	Middle zone	7.673	.157	-3.01	18.3556
	Coastal zone	46.260*	.000	35.57	56.9426
Middle zone	Northern zone	-7.673	.157	-18.35	3.0103
	Coastal zone	38.587*	.000	27.90	49.2699
Coastal zone	Northern zone	-46.260*	.000	-56.94	-35.5767
	Middle zone	-38.587*	.000	-49.26	-27.9040

*The mean difference is significant at the 0.05 level.

TABLE 3: Descriptive statistics of annual rainfall data of coastal zone.

Year	Parameters									
	Annual (mm)	Mean (mm)	Median (mm)	S.D. (mm)	Variance (mm)	Skewness	Kurtosis	Min (mm)	Max (mm)	Range (mm)
1981	899.4	75.0	43.2	81.4	6634.9	1.1	-0.3	1.1	219.6	218.5
1982	1247.5	104.0	60.6	139.7	19519.8	1.7	2.9	0.0	457.3	457.3
1983	539.7	45.0	11.2	65.7	4324.2	1.4	0.9	0.0	183.2	183.2
1984	726.9	60.6	23.8	76.4	5851.3	1.3	0.5	0.0	210.3	210.3
1985	665.6	55.5	36.0	60.6	3680.5	1.5	2.5	0.0	206.8	206.8
1986	495.8	41.3	32.0	42.4	1798.2	0.7	-0.4	0.0	127.6	127.6
1987	931.0	77.6	27.8	102.1	10438.4	1.7	3.1	0.0	339.9	339.9
1988	798.3	66.5	72.1	51.1	2614.5	-0.1	-1.5	0.0	143.2	143.2
1989	949.9	79.2	43.9	82.7	6847.9	0.5	-1.4	0.0	213.8	213.8
1990	655.9	54.7	46.6	47.2	2236.4	0.5	-1.0	0.0	131.7	131.7
1991	1298.1	108.2	30.8	148.9	22176.2	1.4	0.9	0.0	443.5	443.5
1992	359.2	29.9	10.4	51.1	2614.6	2.5	6.7	0.0	176.5	176.5
1993	759.3	63.3	64.9	44.8	2008.1	0.1	-0.9	0.0	132.3	132.3
1994	700.9	58.4	37.5	66.1	4365.8	1.4	1.4	0.0	207.9	207.9
1995	859.2	71.6	31.5	94.1	8858.3	2.0	4.2	0.0	321.1	321.1
1996	992.1	82.7	36.5	103.9	10793.1	1.1	0.0	0.0	283.8	283.8
1997	1191.2	99.3	29.0	168.1	28252.3	2.7	8.3	0.0	598.3	598.3
1998	484.4	40.4	14.1	58.3	3399.8	1.7	2.4	0.0	183.6	183.6
1999	716.0	59.7	31.9	74.7	5590.8	1.6	1.5	2.8	223.6	220.8
2000	394.3	32.9	21.9	34.8	1213.3	0.7	-0.7	0.0	100.1	100.1
2001	779.2	64.9	23.7	74.7	5587.9	0.7	-1.4	0.0	189.4	189.4
2002	842.6	70.2	45.6	89.8	8065.9	2.1	4.9	0.0	315.3	315.3
2003	1061.9	88.5	30.9	131.8	17377.8	2.1	4.7	3.5	446.4	442.9
2004	698.4	58.2	49.1	53.9	2904.5	0.6	-0.9	0.0	147.3	147.3
2005	790.8	65.9	57.9	61.9	3841.2	0.3	-1.6	0.0	157.3	157.3
2006	746.0	62.2	36.7	67.9	4617.8	0.9	-0.1	0.0	202.4	202.4
2007	897.1	74.8	56.5	71.2	5077.8	1.0	0.7	0.0	232.0	232.0
2008	767.3	63.9	39.6	71.4	5108.2	1.5	1.4	0.0	213.2	213.2
2009	1070.0	89.2	27.7	139.8	19570.4	2.2	5.5	0.2	477.3	477.1
2010	957.4	79.8	78.5	73.6	5416.9	0.6	-0.4	0.0	224.3	224.3
2011	893.5	74.5	57.2	86.7	7522.1	1.4	2.1	0.0	285.7	285.7

TABLE 4: Descriptive statistics of annual rainfall of middle zone.

Year	Parameters									
	Annual (mm)	Mean (mm)	Median (mm)	S.D. (mm)	Variance (mm)	Skewness	Kurtosis	Min (mm)	Max (mm)	Range (mm)
1981	1346.7	112.2	95.7	94.9	9013.6	1.4	1.4	0.0	319.8	319.8
1982	1141.2	95.1	90.5	61.5	3788.0	1.1	0.6	30.7	230.1	199.4
1983	1010.2	84.2	90.5	66.9	4482.4	-0.1	-2.1	0.0	163.4	163.4
1984	1337.2	111.4	120.9	92.0	8470.2	0.1	-1.4	0.0	265.7	265.7
1985	1338.4	111.5	125.3	78.7	6202.6	0.4	1.0	2.8	283.6	280.8
1986	1228.1	102.3	108.8	76.5	5855.3	0.0	-1.4	0.0	212.7	212.7
1987	1409.0	117.4	122.0	89.5	8021.7	0.1	-1.1	7.7	254.1	246.4
1988	1382.2	115.2	109.2	65.7	4319.9	0.1	-1.3	21.4	223.1	201.7
1989	1408.5	117.4	130.8	101.9	10382.0	0.8	1.0	0.0	346.4	346.4
1990	1167.7	97.3	109.3	71.7	5143.3	0.4	-0.8	14.6	224.7	210.1
1991	1415.2	117.9	102.4	93.3	8708.8	0.8	0.7	3.1	325.4	322.3
1992	808.1	67.3	66.4	48.7	2380.7	0.3	-0.1	0.0	164.2	164.2
1993	1184.8	98.7	94.8	57.5	3308.8	0.0	-0.2	0.0	204.2	204.2
1994	990.0	82.5	66.0	69.9	4887.3	1.2	1.1	0.0	239.9	239.9
1995	1315.0	109.6	119.6	71.8	5166.8	-0.2	-1.3	0.0	209.8	209.8
1996	1333.8	111.2	86.4	86.7	7526.9	0.9	0.2	5.1	282.9	277.8
1997	1322.7	110.2	95.9	79.4	6314.1	0.3	-1.2	13.7	248.6	234.9
1998	1140.3	95.0	89.8	67.2	4524.6	0.8	0.6	0.3	242.4	242.1
1999	1747.6	145.6	119.5	113.3	12859.2	0.7	-0.1	0.5	374.4	373.9
2000	1220.8	101.7	94.8	70.4	4967.6	0.2	-1.6	10.6	194.8	184.2
2001	1076.4	89.7	84.1	73.0	5338.1	0.1	-1.5	0.0	192.9	192.9
2002	1300.3	108.4	119.4	61.8	3822.2	-0.5	-1.3	6.7	175.3	168.6
2003	1289.4	107.5	79.2	92.4	8550.8	1.2	1.3	10.6	324.9	314.3
2004	1468.5	122.4	102.3	124.0	15380.9	2.0	4.5	3.9	454.2	450.3
2005	1148.7	95.7	68.6	55.8	3121.1	0.5	-1.5	41.2	185.6	144.4
2006	1161.7	96.8	69.7	88.5	7835.3	1.2	0.8	5.0	289.2	284.2
2007	1491.7	124.3	125.4	90.1	8120.3	0.1	-1.1	0.2	262.0	261.8
2008	1551.5	129.3	141.1	78.7	6198.5	-0.3	-1.1	0.0	239.0	239.0
2009	1106.6	92.2	87.4	66.5	4425.1	0.6	-0.2	0.0	224.0	224.0
2010	1324.4	110.4	96.9	78.6	6192.1	0.2	-1.6	6.0	227.0	221.0
2011	1168.8	116.9	133.3	57.3	3286.7	-0.8	0.7	0.0	197.2	197.2

124 mm happened in 2004. The high standard deviation value can be easily correlated with the high rainfall range. The rainfall range signifies the difference between the maximum and minimum annual rainfall. The standard deviation and the range indicate the variability of annual rainfall and hence denote how reliable the rainfall is in terms of its persistence as constant and stable replenishing source. To test whether the annual rainfall data follow a normal distribution, the skewness and kurtosis were computed. Skewness is a measure of symmetry or, more precisely, the lack of symmetry. The data set is said to be symmetric if it looks the same to the left and right from the center point. The skewness for a normal distribution is zero, and any symmetric data should have skewness near zero. Negative values for the skewness indicate that data are skewed to the left and positive values for the skewness indicate that data are skewed to the right.

Kurtosis is a measure of data peakedness or flatness relative to a normal distribution. That is, data sets with a high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. The standard normal distribution has a kurtosis of zero. Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution. Hence the annual rainfall distribution under consideration did not follow normal distribution.

As can be observed from Table 5 the maximum annual rainfall for the period under review occurred in 1991 (2431.5 mm) with corresponding maximum annual mean and standard deviation of 202.6 mm and 182.8 mm, respectively. The standard deviation is a measure of dispersion. A small value indicates that the data is tightly grouped about

TABLE 5: Descriptive statistics of annual rainfall of northern zone.

Year	Parameters									
	Annual (mm)	Mean (mm)	Median (mm)	S.D. (mm)	Variance (mm)	Skewness	kurtosis	Min (mm)	Max (mm)	Range (mm)
1981	1241.6	103.5	83.7	96.4	9298.6	0.2	-1.8	0.0	239.4	239.4
1982	1071.8	89.3	99.6	68.1	4642.2	0.1	-1.0	0.0	204.8	204.8
1983	1060.7	88.4	60.9	95.2	9068.9	0.8	-0.6	0.0	273.9	273.9
1984	1735.2	144.6	77.1	150.6	22682.2	0.6	-1.3	0.0	384.1	384.1
1985	1336.8	111.4	83.0	112.5	12659.3	0.5	-1.6	0.0	284.0	284.0
1986	1370.1	114.2	108.6	97.8	9571.7	-0.0	-2.0	0.0	229.2	229.2
1987	1351.4	112.6	84.8	126.5	16004.2	1.1	0.8	0.0	398.1	398.1
1988	1064.4	88.7	56.2	88.4	7825.1	0.6	-1.2	0.0	246.2	246.2
1989	1479.5	123.3	23.4	161.7	26155.4	1.1	-0.2	0.0	430.2	430.2
1990	1336.7	111.4	114.4	97.7	9553.3	0.4	-0.8	0.0	296.5	296.5
1991	2431.5	202.6	179.6	182.8	33425.1	0.3	-1.4	0.0	498.1	498.1
1992	970.7	88.2	58.9	88.7	7872.5	0.7	-0.4	0.0	257.4	257.4
1993	1003.2	83.6	44.8	95.1	9052.5	1.5	2.1	0.0	316.3	316.3
1994	1197.9	99.8	116.8	93.7	8780.1	0.0	-1.9	0.0	226.9	226.9
1995	1680.8	140.1	145.6	125.7	15821.9	0.2	-1.4	0.0	350.4	350.4
1996	1539.8	128.3	149.1	119.2	14226.2	-0.1	-2.1	0.0	274.6	274.6
1997	1387.9	115.7	84.8	107.8	11635.4	0.4	-1.5	0.0	277.2	277.2
1998	982.5	89.3	60.3	81.1	6583.3	0.2	-1.7	0.0	205.5	205.5
1999	1580.8	131.7	64.9	142.4	20300.0	0.8	-0.9	0.0	394.4	394.4
2000	1375.6	114.6	85.0	109.4	11972.7	0.5	-1.3	0.0	293.2	293.2
2001	915.6	76.3	38.7	100.1	10016.8	1.3	0.7	0.0	291.8	291.8
2002	1453.8	121.2	155.1	97.7	9550.9	-0.2	-1.8	0.0	240.7	240.7
2003	1423.5	118.6	95.0	110.0	12101.4	0.9	-0.5	0.7	314.0	313.3
2004	1500.6	125.1	109.4	110.2	12157.7	0.6	-0.8	0.0	322.8	322.8
2005	1498.8	124.9	95.7	121.3	14727.5	1.0	0.1	0.0	374.3	374.3
2006	1033.3	86.1	62.7	96.5	9314.4	1.2	0.7	0.4	284.6	284.2
2007	1148.6	95.7	89.1	76.3	5820.8	0.1	-1.6	0.0	208.9	208.9
2008	1853.5	154.5	133.6	151.0	22802.6	0.8	0.2	0.0	479.1	479.1
2009	1617.5	134.8	139.1	109.4	11981.1	0.1	-1.7	0.0	294.7	294.7
2010	1107.2	92.3	86.3	82.0	6729.4	0.6	-0.3	0.0	244.5	244.5

the mean. A high value indicates that the data is spread widely on either side of the mean. A high standard deviation also suggests that year-to-year fluctuations are high while a low standard deviation indicates that fluctuations are lower. In other words, rainfall with a high standard deviation is considered more volatile than rainfall with a low figure. The minimum annual rainfall occurred in 2001 with an amount of 915.6 mm for the years under consideration.

It is evident from Table 6 that the coefficient of variation for the months of April through July (major season) is less than 0.5 which indicates lower variability from the mean and similar observation is made for the months of September and October (minor season). The low coefficient of variability recorded for the aforementioned months is an indication of highly dependable rainfall. Reference [11] stated that the CV is an indication of the degree of precision to which the treatments are compared and is a good index of the reliability of the experiment. Reference [11] further indicated

that the higher the CV value, the lower the reliability of the experiment.

The standard deviation is one way of summarizing the spread of a probability distribution; it relates directly to the degree of uncertainty associated with predicting the value of a random variable. High values reflect more uncertainty than low values. Table 6 clearly revealed that September in middle climatic zone had the highest standard deviation. The highest amount of average monthly rainfall was recorded in June (182.1 mm) and contributed to 14.3% of annual rainfall, followed by September with 12.8%, and the lowest was in January with 1.4% of annual total followed by December with 2.3%. From the analysis, it was observed that rainfall is usually at its peak between April and July in the major season and between September and October in the minor season.

The precipitation changes from month to month are considerable in years. When the standard deviation values are examined, it is observed that the standard deviation values

TABLE 6: Statistical summary of monthly rainfall data of middle zone.

Parameter (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	18.2	52.7	102.3	133.3	154.9	182.1	132.2	94.6	163.2	160.3	47.3	30.4
Median	8.2	43.5	100.2	132.0	147.9	165.1	120.0	84.4	164.2	154.8	42.0	21.6
S.D.	22.2	44.8	59.6	57.2	66.8	78.3	58.2	66.4	79.5	52.9	32.3	32.2
Variance	490.9	2009.3	3553.4	3274.6	4460.5	6127.1	3384.8	4403.6	6332.2	2801.6	1041.9	1039.6
Skewness	1.1	2.0	0.8	-0.1	0.7	0.9	0.5	0.7	1.5	0.9	1.4	0.9
Kurtosis	0.4	4.9	0.5	-0.2	0.2	0.2	0.1	-0.3	4.9	1.5	1.7	-0.2
Min	0.0	5.8	20.3	6.9	35.5	74.4	30.2	9.4	47.5	77.4	5.8	0.0
Max	78.4	212.7	265.7	255.6	325.4	374.4	283.6	254.1	454.2	319.8	133.8	103.4
Range	78.4	206.9	245.4	248.7	289.9	300.0	253.4	244.7	406.7	242.4	128.0	103.4
Sum	564.0	1632.8	3169.9	4132.9	4800.7	5645.0	4097.1	2933.1	5060.3	4968.1	1419.8	911.8
CV	1.2	0.9	0.6	0.4	0.4	0.4	0.4	0.7	0.4	0.3	0.6	1.0

TABLE 7: Statistical summary of monthly rainfall data of coastal zone.

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean (mm)	3.3	23.2	61.0	107.3	150.4	206.2	64.9	19.8	56.0	78.7	29.9	11.2
Median (mm)	0.0	11.2	49.0	86.7	145.7	174.2	44.2	10.8	33.9	65.2	22.0	2.5
S.D. (mm)	6.1	30.8	45.8	67.8	60.4	138.5	87.6	31.7	71.0	63.2	29.0	18.3
Variance (mm)	36.8	950.2	2098.5	4606.9	3645.8	19185.3	7675.3	1005.1	5050.3	3997.5	841.2	336.0
Skewness	2.2	1.4	0.7	1.2	0.0	1.2	3.0	3.2	2.5	0.6	0.8	2.6
Kurtosis	4.8	0.9	-0.0	1.9	-0.5	1.1	11.4	12.9	7.7	-0.8	-0.1	6.9
Min (mm)	0.0	0.0	0.0	18.3	34.5	47.0	1.2	0.0	0.0	0.5	0.0	0.0
Max (mm)	22.6	96.3	181.1	324.7	269.6	598.3	443.5	160.6	339.9	210.9	107.6	77.7
Range (mm)	22.6	96.3	181.1	306.4	235.1	551.3	442.3	160.6	339.9	210.4	107.6	77.7
Sum (mm)	102.0	719.5	1890.7	3325.0	4663.9	6391.7	2012.5	612.4	1735.9	2440.0	928.3	347.0
CV	1.8	1.3	0.7	0.6	0.4	0.6	1.3	1.6	1.2	0.8	0.9	1.6

of most months (January, February, July, August, September, and December) are higher than the averages of these months (See Table 7). This relation between the standard deviation and the average values indicates that the deviation from the normal distribution cannot be ignored. This fact is especially supported by the coefficients of variation of these months which are over one or close to one. These show that, in coastal zones, the precipitation values are much different from the average. The fact that the CV values are so high is an indication of the rainfall being highly variable and not dependable or reliable or can be attributed to the length of data set being used or the quality of data.

The lower the coefficient of variation of rainfall amount in any month, the lower the variability and the greater the dependability. Coefficient of variation values less than 0.5 shows lower variability from the mean. Table 8 reveals that from June to September the rainfall variability is low and therefore highly dependable. Considering the coefficient of variation, September shows the minimum variation from year to year, compared to the rest of the months. However, since the coefficients of variation of each of the four months (June–September) are less than 0.5, the changes of precipitation from year to year in these months are low. September is the month with the highest mean monthly rainfall of 252.3 mm followed by August with 227.6 mm. Incidentally

the above mentioned months traditionally fall within the minor season which usually records lower rainfall. This change in the rainfall season could be attributed to the so-called climate change. The month with the lowest rainfall is December (7.6 mm) followed by January (7.7 mm).

The results of the linear regression trend analysis are presented in Tables 9, 10, and 11, respectively, covering northern, middle, and coastal zones, respectively, of the Volta Region. In these trend tests, trend of rainfall for 30 years from January to December has been computed for each month independently.

The linear trend lines of the monthly rainfall indicated a downward trend in May, June, and September and an upward trend for other months and annual rainfall data for the northern zone. Since the probability value (P value) from the regression analysis for the slopes of the monthly and annual trend lines was greater than the significant level $\alpha = 0.05$, the null hypothesis (H_0 : there is no trend in the data, fail to reject. That means there is no statistically significant trend in the annual and monthly rainfall data for northern zone. Additionally, the R -square statistic also indicated a very weak relationship between the variables, rainfall, and year.

Table 10 revealed downward trends in the rainfall for the months of March, May, July, October, and November and the rest of the months recorded upward trend in the rainfall data

TABLE 8: Statistical summary of monthly rainfall data of northern zone.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean (mm)	7.7	11.1	38.2	93.9	128.8	217.2	210.9	227.6	252.3	142.5	22.2	7.6
Median (mm)	0.0	0.3	35.2	82.3	125.4	213.5	201.9	243.6	235.2	119.8	6.3	0.7
S.D. (mm)	16.0	19.6	31.6	61.3	80.0	83.4	94.0	80.3	70.3	93.9	31.1	16.0
Variance (mm)	255.1	383.7	1000.6	3756.6	6394.8	6952.4	8831.9	6445.9	4947.0	8812.8	964.4	255.3
Skewness	2.1	1.8	0.7	0.9	1.2	0.5	1.7	-0.3	0.9	1.3	1.6	2.8
Kurtosis	3.8	1.8	0.1	0.4	3.1	0.2	3.6	-0.5	0.0	2.4	2.1	7.4
Min (mm)	0.0	0.0	0.0	7.3	6.0	93.6	91.7	73.0	146.8	9.2	0.0	0.0
Max (mm)	60.0	65.7	117.3	245.6	398.6	430.2	498.1	373.5	400.6	440.7	112.0	66.1
Range (mm)	60.0	65.7	117.3	238.3	392.6	336.6	406.4	300.5	253.8	431.5	112.0	66.1
Sum (mm)	231.6	323.3	1107.5	2817.5	3864.7	6516.0	6326.4	6827.3	7567.5	4274.7	665.9	228.9
CV	2.1	1.7	0.8	0.6	0.6	0.3	0.4	0.3	0.2	0.6	1.3	2.1

TABLE 9: Regression statistic results for annual and monthly rainfall for northern zone.

Month	Regression equation	R-square	P value	Statistically significant
Jan	$Y = 0.35X - 681.8$	0.04	0.32	No
Feb	$Y = 0.30X - 592.4$	0.02	0.47	No
Mar	$Y = 0.19X - 355.3$	0.00	0.80	No
April	$Y = 1.19X - 2285.5$	0.03	0.38	No
May	$Y = -2.06X + 4231.2$	0.05	0.22	No
June	$Y = -1.73 + 3672.1$	0.03	0.30	No
July	$Y = 0.91X - 1596.4$	0.01	0.69	No
Aug	$Y = 0.68X - 1126.2$	0.01	0.75	No
Sept	$Y = -0.57X + 1392.3$	0.01	0.65	No
Oct	$Y = 1.73X - 3318.1$	0.03	0.41	No
Nov	$Y = 1.05X - 2064.5$	0.09	0.12	No
Dec	$Y = 0.47X - 927.3$	0.07	0.17	No
Annual	$Y = 2.51X - 3651.9$	0.00	0.80	No

TABLE 10: Regression statistic results for annual and monthly rainfall for central zone.

Month	Regression equation	R-square	P value	Statistically significant
Jan	$Y = 0.31X - 609.8$	0.02	0.50	No
Feb	$Y = 0.34X - 629.0$	0.00	0.73	No
Mar	$Y = -0.99X + 2095.1$	0.02	0.39	No
April	$Y = 1.49X - 2856.9$	0.06	0.22	No
May	$Y = -1.53X + 3212.6$	0.04	0.24	No
June	$Y = 2.33X - 4486.8$	0.07	0.15	No
July	$Y = -0.97X + 2080.8$	0.02	0.38	No
Aug	$Y = -0.47X + 1041.2$	0.00	0.70	No
Sept	$Y = 2.74X - 5315.2$	0.09	0.09	No
Oct	$Y = -0.72X + 1594.7$	0.02	0.46	No
Nov	$Y = -0.27X + 599.3$	0.01	0.67	No
Dec	$Y = 0.22X - 412.0$	0.00	0.77	No
Annual	$Y = 2.02X - 2760.5$	0.01	0.71	No

for the middle zone. However, the trends are not statistically significant. This argument is buttressed by the P values of the linear regression analysis being greater than $\alpha = 0.05$.

Annual rainfall for coastal zone showed upward trend; however, there is a decreasing trend in the months of March, April, May, July, September, and November and the rest of

the months of the year revealed an increasing trend. Again, these trends are insignificant statistically as indicated by the P values.

Figure 4 clearly reveals that for the period under consideration for middle zone the highest mean monthly rainfall was recorded in June and the lowest in January. It is also

TABLE 11: Regression statistic results for annual and monthly rainfall for coastal zone.

Month	Regression equation	<i>R</i> -square	<i>P</i> value	Statistically significant
Jan	$Y = 0.80X - 154.7$	0.01	0.53	No
Feb	$Y = 0.90X - 1774.88$	0.07	0.15	No
Mar	$Y = -1.16X + 2384.64$	0.05	0.20	No
April	$Y = -0.35X + 811.97$	0.00	0.77	No
May	$Y = -0.87X + 1881.74$	0.02	0.45	No
June	$Y = 3.38X - 6540.3$	0.05	0.24	No
July	$Y = -1.65X + 3357.27$	0.03	0.35	No
Aug	$Y = 0.32X - 617.20$	0.01	0.64	No
Sept	$Y = -0.04X + 132.05$	0.00	0.96	No
Oct	$Y = 1.66X - 3234.97$	0.06	0.21	No
Nov	$Y = -0.26X + 545.28$	0.01	0.65	No
Dec	$Y = 0.18X - 353.72$	0.01	0.64	No
Annual	$Y = 2.19X - 3562.80$	0.01	0.70	No

evident from the graph that the highest average minor season rainfall occurred in September.

For the northern zone the highest average monthly rainfall for the period under review as indicated in Figure 4 was recorded in September which is a minor season for the northern climatic zone. The result clearly indicated that the peak mean monthly rainfall in the minor season was more than the major season which suggested a discrepancy. However, this could be attributed to climate change effects.

The graph for coastal zone revealed that December and January were the driest months. The highest rainfall occurred in June for the major season while the highest corresponding minor season rainfall was recorded in October.

4. Conclusion

The rainfall characteristics especially variability and trend are necessary for the proper design of hydro related schemes such as clean water supply, reservoir, and storm water channels in rapidly growing regions like Volta Region. From the results of the linear regression analysis, there is statistically insignificant increasing trend in annual mean rainfall data among the zones under study. The mean monthly rainfall data from the linear regression analysis revealed upward trend in some months and downward trend in others. However, the results indicated statistically insignificant trend in the monthly rainfall and very weak correlation between rainfall and period. It is evident from the results that there is no significant detectable effect of climate change on both the annual and monthly trend in Volta Region.

Comparatively coastal zone recorded the lowest maximum and minimum annual rainfall of 1298.1mm and 359.2mm, respectively, followed by the middle zone with 1747.6mm and 808.1mm. The northern zone recorded the highest maximum annual rainfall of 2431.5 mm and the minimum of 915.6 mm in the years 1991 and 2001, respectively.

Further studies are required to be carried out to establish other rainfall characteristics such as extreme rainfall, rain days, and other climate change parameters for this region to verify whether the significant trend has occurred and also

FIGURE 4: Average monthly rainfall for the three zones from 1981 to 2010.

to establish a correlation between temperature and extreme rainfall.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

- [1] R. F. Adler, G. J. Huffman, D. T. Bolvin, S. Curtis, and E. J. Nelkin, "Tropical rainfall distributions determined using

- TRMM combined with other satellite and rain gauge information,” *Journal of Applied Meteorology*, vol. 39, no. 12, pp. 2007–2023, 2000.
- [2] J. R. Gat, *Planning and Management of a Sustainable and Equitable Water Supply under Stress of Water Scarcity and Quality Deterioration and the Constraints of Societal and Political Divisions: The Case for a Regional Holistic Approach*. Department of Environmental Science and Energy Research, The Weizmann Institute of Science, Rehovot, Israel, 2004.
- [3] E. C. Kipkorir, “Analysis of rainfall climate on the Njemps Flats, Baringo District, Kenya,” *Journal of Arid Environments*, vol. 50, no. 3, pp. 445–458, 2002.
- [4] S. Herath and U. Ratnayake, “Monitoring rainfall trends to predict adverse impacts—a case study from Sri Lanka (1964–1993),” *Global Environmental Change*, vol. 14, pp. 71–79, 2004.
- [5] M. N. Almasri, A. Jayyousi, and A. Jarrar, “Statistical analysis of long-term spring yield in a semi-arid watershed: a case study from Palestine,” in *Proceedings of the International Conference Water: Values and Rights*, Ramallah, Palestine, May 2005.
- [6] Volta Regional Coordinating Council (VRRC), “Volta Region,” 2013, <http://www.ghananation.com/volta/>.
- [7] S. Brian Jr. and M. O. Rodgers, “Urban form and thermal efficiency how the design of cities influences the Urban heat island effect,” *Journal of the American Planning Association*, vol. 67, no. 2, pp. 186–198, 2001.
- [8] M. J. Manton and M. Bonell, “Climate and rainfall variability in the humid tropics,” in *Hydrology and Water Management in the Humid Tropics-Hydrological Research Issues and Strategies for Water Management*, M. Bonell, M. M. Hufschmidt, and J. S. Gladwell, Eds., pp. 13–33, Cambridge University Press, Cambridge, UK, 1993.
- [9] S. Nieuwolt, *Tropical Climatology: An Introduction to the Climates of the Low Latitudes*, John Wiley & Sons, New York, NY, USA, 1977.
- [10] R. E. Dewar and J. R. Wallis, “Geographical patterning of interannual rainfall variability in the tropics and near tropics: an L-moments approach,” *The American Meteorology Society*, vol. 12, no. 12, pp. 3457–3466, 1999.
- [11] K. A. Gomez and A. A. Gomez, *Statistical Procedures for Agricultural Research*, John Wiley & Sons, New York, NY, USA, 2nd edition, 1984.