



Analysis of temperature and rainfall trends as proxy for seasonal climatic variability in South-Central Ghana

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Changing climates have had considerable effect on the erratic rainfall and temperature patterns over the years for both locally and nationally for Ghana. The main objective of this paper is to perform a Mann-Kendall trend analysis of rainfall and temperature variables spanning the period 1986-2015 for the South-central districts of Ghana. The trend analysis was used as proxies to analyze the changing trends of rainfall and temperature regimes within four seasons Pre-Harmattan, Harmattan, Post-Harmattan and the Wet Seasons, to correspond with local 'Autumn', 'Winter', 'Spring' and 'Summer' respectively. Results for temperature indicated that the maximum temperature for the period was 29.55°C recorded in the Post-Harmattan season in the years 1990 and 1998; whereas the minimum temperature was 22.5°C recorded in the Harmattan season in the year 2008. Results for the rainfall indicated that the month of June which is the Wet season recorded the maximum rainfall of 379.5mm in the year 2010; whereas the minimum rainfall was recorded in the Harmattan months. The results indicate that rainfall and temperature do not have monotonic trends. This has implications for future availability of water for household and other applications.

INTRODUCTION

Climate variability has received increased attention in the last few years. To understand the issue relating to climate variability, it is important to discuss climate and climate change. These two factors are important in discussions relating to climate variability (Easterling et al. 2016; Magreth S Bushesha, 2018). The climate of a region refers to the average weather for a given period. It seeks to describe the distinctive weather conditions for a particular region based on long-term averages (Lawrence and Chase 2010; Crane et al. 2011). Climate is typically determined based on the weather conditions in one region for at least 30 years. Weather may refer to the routine state of the atmosphere and its temporary deviations such as temperature, humidity, and precipitation or wind (Food and Agricultural Organization 2015).

Although an appreciable number of studies have been conducted on the impacts of climate variability and climate change in developing countries, limited studies consider the climatic trends and spatial variations in such countries (Intergovernmental Panel on climate change, IPCC 2014, Challinor et al. 2014, Wheeler & von Braun 2013, Waha et al. 2013, Rivington et al. 2013; Mohan Singh and Ram Niwas, 2018; Mandale et al. 2019). Knowledge on the trends of rainfall and precipitation in the peri-urban district using the Mann-Kendall trend test could assist in anticipating future impacts of climate variability and climate changes in the region and country as a whole.

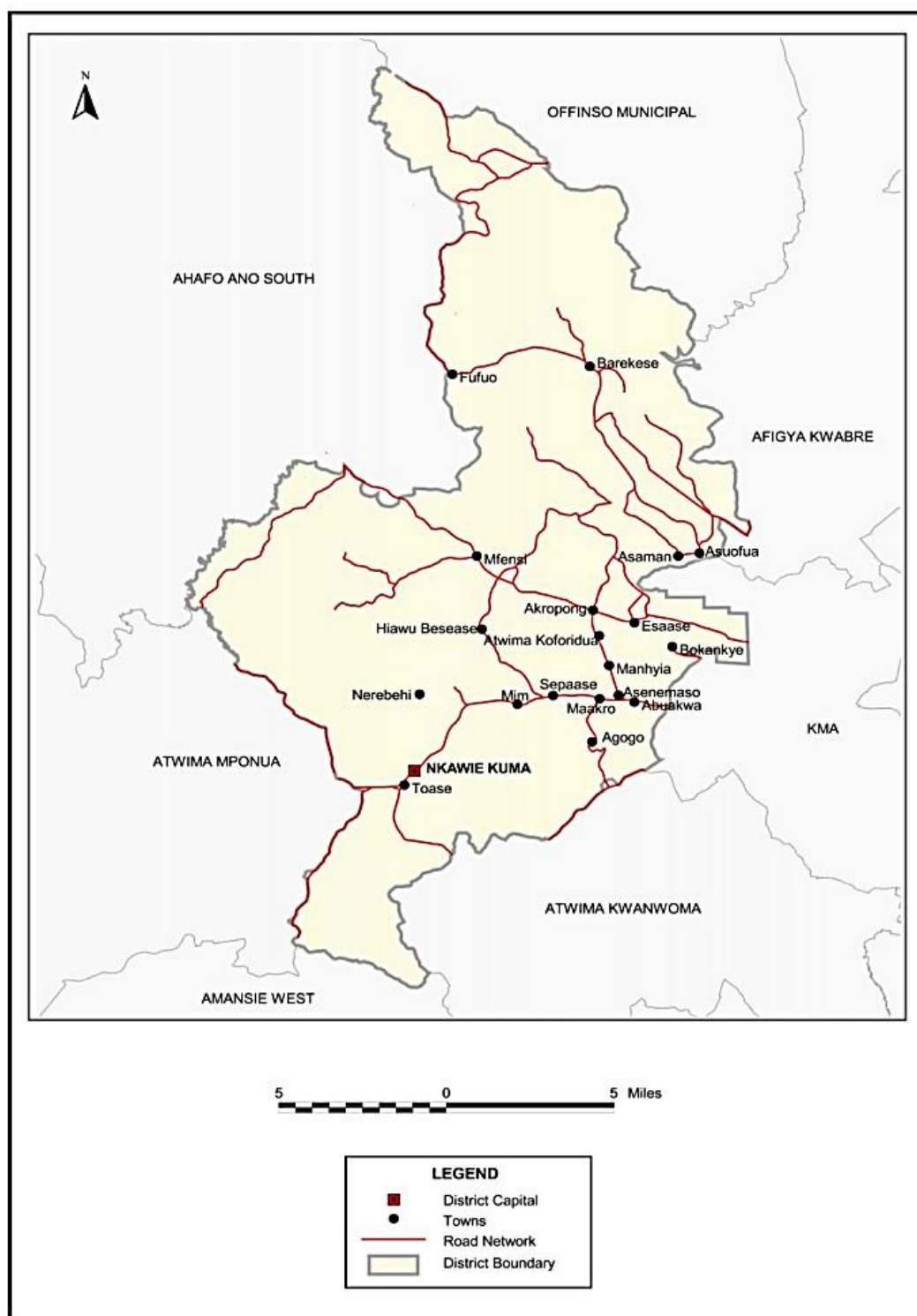
The Mann-Kendall trend test is usually used to analyze the trend of climatic data for a period of time. This is method is used to find out whether or not there is an increasing or decreasing trend. In as much as there are many other software like the SPSS available to estimate trends, the Mann-Kendall trend test is a non-parametric method and less sensitive to outliers as compared to other software which are very sensitive to outliers. Also, the Mann-Kendall trend test does not specify whether the trend is linear or nonlinear. Furthermore, the Mann-Kendall trend test is able to detect the trend and normalize the p-value for a significant test. The Mann-Kendall statistic is usually compared to a critical value, in order to test whether the trend in rainfall or temperature is increasing, decreasing or no trend (Sorecha 2017; Fitsum Bekele et al. 2017; Mandale et al. 2019).

Langat et al. 2017 also employed the Mann-Kendall trend test to investigate temporal variability and trends of rainfall and discharges in Tana River Basin in Kenya. A monthly rainfall data was used from ten stations spanning from 1967 to 2016 and daily stream flow data time series of observations from 1941 to 2016 (75 years) were analyzed. The objective of using this method was to capture and detect inter-annual and seasonal variability and monotonic trends. Results from the analysis showed that stream flow is largely dependent on increasing rainfall at the highlands.

Gavrilov et al. 2017 applied the Mann-Kendall trend test to assess the significance of temperature trends. Results indicated that, there was an increasing temperature trend in the study area. Our justification for the use of the temperature and rainfall as the climatic variables under study is based on the fact that studies on climate variability in Africa

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Source: Ghana Statistical Service, GIS

Figure 1 Map of the study area showing the South-central Districts

have mostly focused on temperature and rainfall fluctuations (Rivington et al. 2013; Lawrence and Chase 2010, Crane et al. 2011, Harris 2007, Maponya & Mpandeli 2012, Legesse et al. 2003). In Ghana, various literature have also tended to follow this same approach (Amikuzino and Donkor 2012; Asante and Amuakwa-Mensah 2014). The tropical rain belt, which moves between the northern tropic and the southern tropic in

a year, controls the rainfall season of Ghana, which is divided into two main seasons the wet and dry in the South central regions of Ghana.

Until now the understanding of the seasons in the South-central Ghana especially, within the tropical region which are controlled by the inter-tropical convergence zone (ITCZ) is not adequate. This is particularly so, regarding the erratic climatic patterns that have

characterized the region in terms of the late onset of the rain and the early cessation that have been occurring in the last two decades. This trend in the climatic patterns has caused a hitherto, clear Wet and Harmattan seasons, to be mixed with other inter-seasonal climatic patterns.

This paper, in addition to analyzing the regular two main climatic season that characterizes the south-central part of Ghana, also identified two additional inter-seasonal periods to analyze the climatic data along the universal seasons of ‘Spring’, Summer’, ‘Autumn’ and ‘Winter’ as Post-harmattan, Wet, Pre-harmattan and Harmattan (dry) seasons respectively. Therefore, the focus of this paper is to employ the Mann-Kendall trend test to analyze climatic trends in rainfall and temperature for a period of 30 years in the South-Central districts of Ghana.

MATERIALS AND METHODS

Profile of the study area

The study was conducted in the south-central part of Ghana (Figure 1), which lies between latitude 6° 32'N and 6° 75'N between longitude 1°45' and 2° 00' West. It is located in the western part of the Ashanti region. It shares common boundaries with other districts (Ahafo-Ano to the South, Offinso Municipal to the North, Atwima-Mponua Districts to the West, Amansie West and Atwima-Kwanwoma Districts to the South and the Kumasi Metropolis and Afigya-Kwabre Districts to the East. It covers approximately 294.84 km². The district capital is Nkawie. And has a total population of about 164,494 as at the 31st December 2014 (GLSS, 2014; District planning Unit 2014). The topography of the District is undulating with an average height of 80 metres above sea level. (GLSS2014, District Planning Unit 2014). The forest cover type is predominantly semi-deciduous forest.

The District lies within the wet semi-equatorial zone marked by double maximum rainfall ranging between 170cm and 185cm per annum. The major rainfall season is from mid-March to July and minor season is between September and mid-November. Rainfall in the district is not distributed evenly throughout the year. Its density and pattern are also becoming unpredictable and this poses considerable risk to rain-fed agriculture and food crop yield. Temperature is fairly uniform ranging between 27°C (August) and 31°C (March) and a mean relative humidity of 87% to 91%. The lowest relative humidity usually occurs in February/April when it averages between 83 -87 in the morning and 48-67 in the afternoon (GLSS 2014, District Planning Unit 2014). The districts in the area have good soils (semi-deciduous forest) which are suitable for farming activities of which crop yield can be quantified and measured as against climate variability.

Data collection and analysis

Rainfall and temperature were the climatic variables used in assessing the climate variability and climate change in the district, since they present the most conspicuous variables for climatic analysis (Nikulin et al. 2017, Pérez-Zanón et al. 2017). The study made use of data acquired on the variations in climatic trends of temperature and rainfall in the study area examined through analysis of long-term meteorological data base from the Ghana Meteorological Agency (GMet). The GMet made available, data for rainfall and temperature over 30 years (1986 to 2015). A time frame of not less than 30 years is qualified in studying the trends of climate variables (IPCC 2007).

The Mark Sens Excel template (Mann-Kendall test for trend and Sen's slope estimates) was used in this study to analyze the climatic trend over 30 years, and is developed for detecting and estimating trends in the time series of the annual values of atmospheric and rainfall

concentrations. The Mann-Kendall trend test is a non-parametric rank-based procedure, robust against the influence of extremes (Karpouzou et al. 2010, Partal & Kahya 2006). The technique is adopted in cases with non-normally distributed time series data, that is, data containing outliers and nonlinear trends.

Similarly, the trend was quantified using Sen's slope method. Sen's slope is another index to quantify the trend using the non-parametric procedure developed by Sen (Sen 1968). The Sen's method uses a linear model to estimate the slope of the trend and the variance of the residuals should be constant in time. These methods offer many advantages that have made them useful in analyzing atmospheric chemistry data. Missing values are allowed and the data need not conform to any particular distribution. Besides, the Sen's method is not greatly affected by single data errors or outliers (Salmi 2002).

The Mann-Kendall test statistic S is calculated using the formula: Under the hypothesis of independent and randomly distributed random variables, when $n \geq 18$, the S statistic is approximately normally distributed, with zero mean and variance in equation 1 as follows:

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

where x_j and x_k are the annual values in years j and k , $j > k$, respectively, and

$$\text{sgn}(x)(x_j - x_k) = \begin{cases} 1 & \text{if } x_j - x_k > 0 \\ 0 & \text{if } x_j - x_k = 0 \\ -1 & \text{if } x_j - x_k < 0 \end{cases} \dots\dots\dots 2$$

The method of calculating the Sen's slope estimator used a time series of equally spaced data. Sen's method proceeds by calculating the slope as a change in measurement per change in time, as shown here in equation (3):

$$Q = \frac{X_j - X_i}{j - i} \dots\dots\dots 3$$

Where: Q = slope between data points X_j and X_i ; X_j = data measurement at time j , X_i = data measurement at time i , j = time after time i , X_j and X_i constitute the pairs of observations identified by place in the series. The median of these estimates is Sen's estimator of slope.

RESULTS

This section integrates the analyzed results obtained from the Mann-Kendall together with the Sen's slope estimation. These constitute the main outcomes that have been analyzed and presented in the discussion section.

Analysis of Temperature and Rainfall

The table 1 shows the trend of temperature for the 30-year period from January to December using 'Mankesen' statistics and trend analysis. Figure 2 show the Harmattan season which is the first quarter season in

Table 1 Result for MAKESENS Temperature Trend Analysis

Time series	First year	Last Year	N	Test Z	Signific.	Q
January	1986	2015	30	-3.03	**	-0.05
February	1986	2015	30	-3.66	***	-0.059
March	1986	2015	30	-2.56	*	-0.044
April	1986	2015	30	-2.27	*	-0.017
May	1986	2015	30	-0.34		-0.004
June	1986	2015	30	1.72	+	0.018
July	1986	2015	30	2.7	**	0.043
August	1986	2015	30	3.96	***	0.044
September	1986	2015	30	2.13	*	0.02
October	1986	2015	30	-0.09		0
November	1986	2015	30	-3.38	***	-0.043
December	1986	2015	30	-0.43		-0.01
Mean	1986	2015	30	-1.53		-0.008

*, ** and *** trend is significant at 0.05, 0.01 and 0.001 respectively

the Ashanti region ranging from the month of December to January. It can be observed that temperature ranges between 23°C and 28°C. The year 2008 recorded the lowest amount of temperature in the month of January whereas the year 1987 recorded the highest temperature in the month of November. Temperature trends over the 30year period have been fluctuating with the month of November being the hottest month and the month of January being the month with the lowest temperature among the three months. However there is a slight decline in temperatures for the period. Data trends are close to each other meaning there is not much difference between temperatures in these three months.

Also, the figure 2 depicts the post-Harmattan season which is also the second quarter season in the Ashanti region. It starts from the month of February and ends in April. It is observed that temperature is between 25°C and 30°C. The year 2000 recorded the lowest temperature in the month of February whereas the year 1990 recorded the highest temperature in the month of March. Temperature trends over the 30 year period have been fluctuating with the month of March being the hottest month and the month of April being the Month with the lowest temperature among the three months. This could be because April is the transition month to the wet season. However there is a general decline in temperatures for the period.

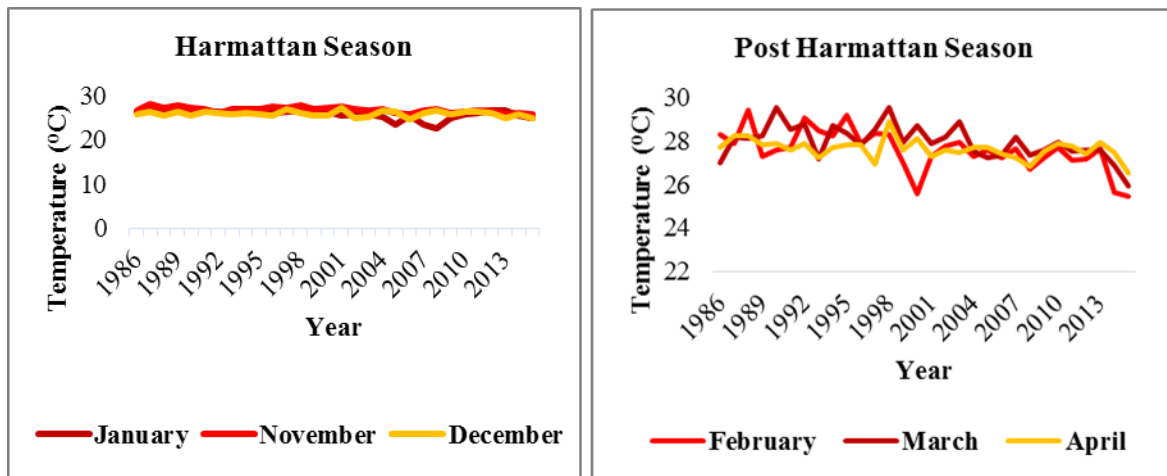
Figure 3 shows the third quarter season from the months of May to July which is usually the wet season in the Ashanti region. It is can be seen that temperature ranges between 24°C and 29°C. Temperatures in this season are lower than that of the previous season. The year 1992 recorded the lowest amount of temperature in the month of July whereas the year 2013 recorded the highest temperature in the month of May. Temperature trends over the 30year periods have been fluctuating with

the Month of May being the hottest month and the month of July being the month with the lowest temperature among the three months. Data set are more sparsely distributed than that of the dry season. However, there is a slight increase in temperatures for the period.

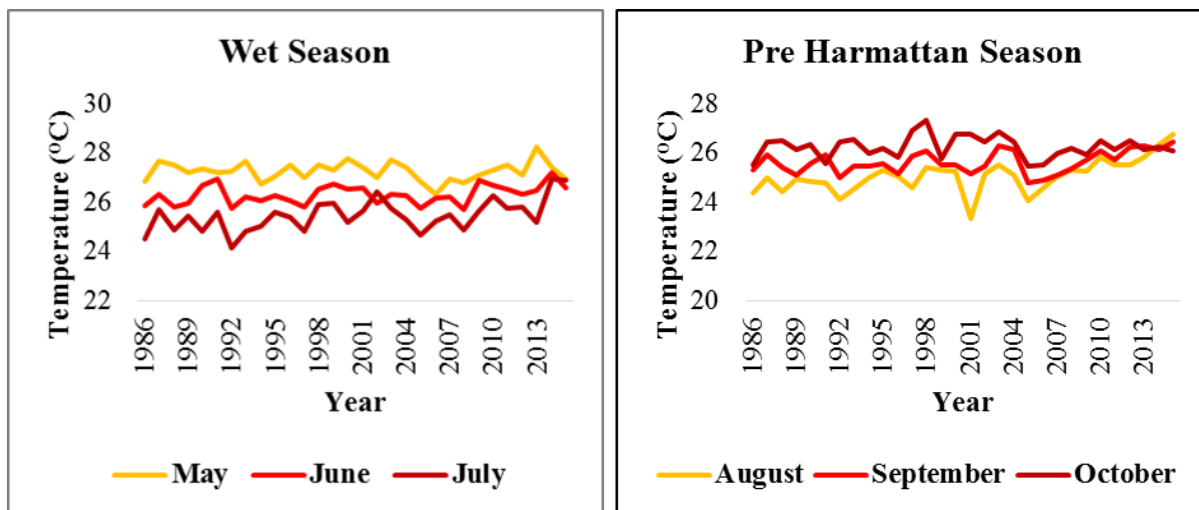
The pre-Harmattan season in the Ashanti region is from August to October. It is also referred to as the fourth quarter season. August is usually known to be the coolest month and this data set confirms it. It is further observed from figure 3 that temperature ranges from 23°C to 28°C. The year 2001 recorded the lowest amount of temperature for the month of August whereas the year 1998 recorded the highest temperature in the month of October. Temperature trends over the 30year period have been fluctuating with the Month of October being the hottest month and the month of August being the Month with the lowest temperature among the three months. However, there is a general decline in temperatures for the period 1986 to 2005 and a slight increase from 2005 to 2015.

Temperature spanning 1986-2015

Table 1 shows a summary of the results for the 30-year period for temperature trends. It can be observed that, January to April, June to September and November are statistically significant and therefore we reject the null hypothesis of each month. Whereas the months of May, October and December are not statistically significant meaning that there is no correlation between the variables temperature and years. Therefore, the Mann-Kendall hypothesis failed to reject the null hypothesis of no monotonous trend was upheld because temperature did not show any monotonous trend, hence, we failed to reject the null hypothesis.



Figures 2 (a & b) Temperature trends from 1986-2015 for Harmattan and Post-Harmattan seasons



Figures 3 (a & b) Temperature trends from 1986-2015 for the Wet and Pre Harmattan seasons

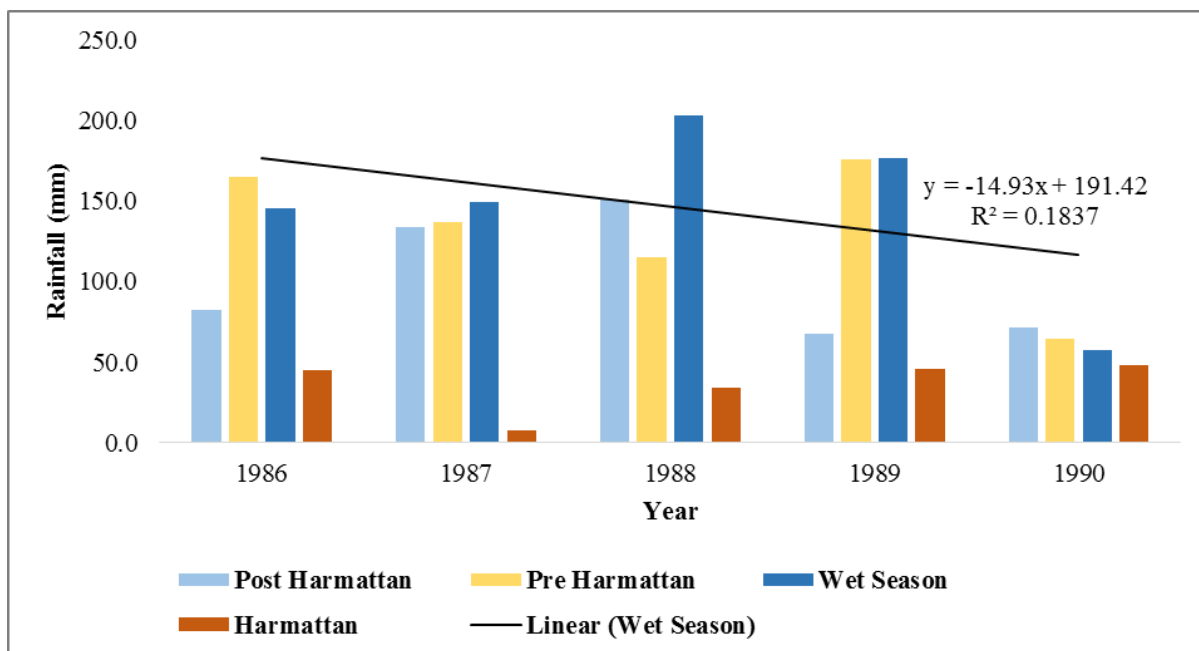


Figure 4 Graph showing composite Rainfall trends for the seasons from 1986-1990

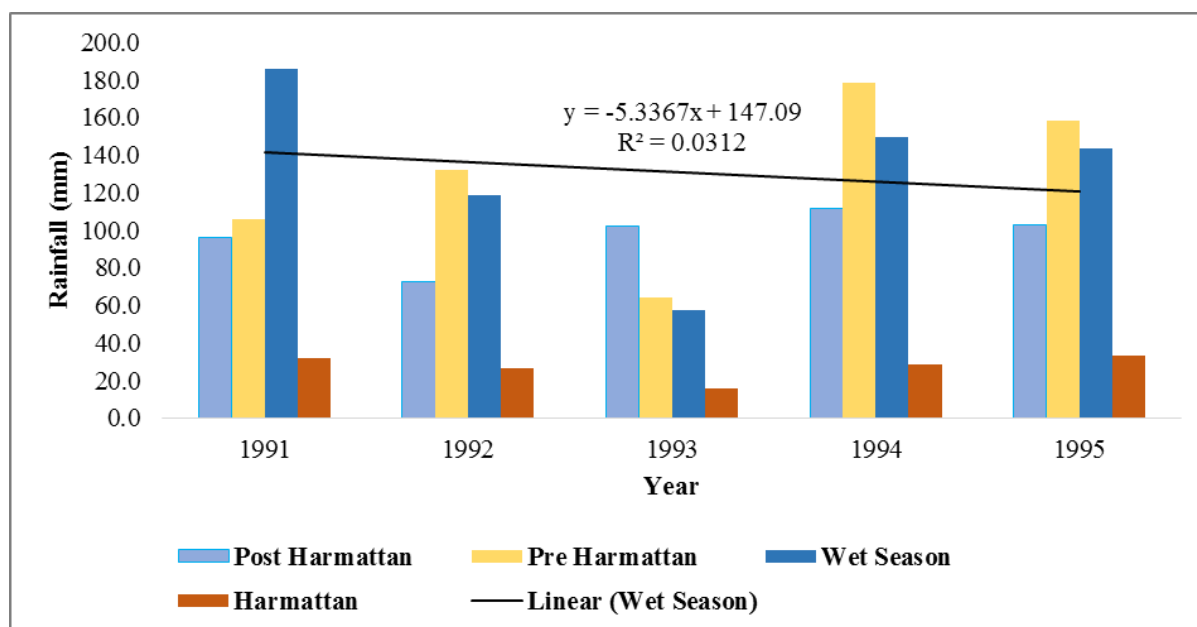


Figure 5 Graph showing composite Rainfall trends for the seasons from 1991-1995

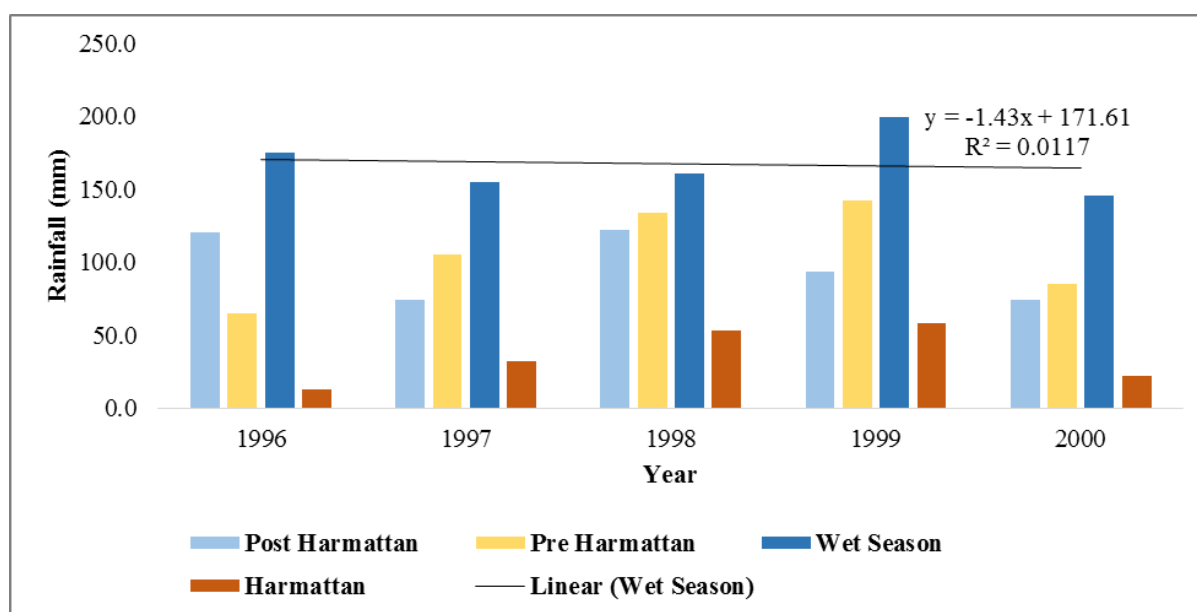


Figure 6 Graph showing composite Rainfall trends for the seasons from 1995-2000

Observing temperature trends for the years 1986-2015, it can be seen that temperature trends among the months for the 30- year period do not show a regular pattern. Whereas the months January, February, March, April, May, November and December are experiencing a decline in temperature, the months June, July, August and September are experiencing an increase in temperature. However, we reject the null hypothesis for majority of the months for the 30 year period.

The causes of climate variability per the information received indicate that anthropogenic activities are the main causes of these variations. These activities include; increased sand winning for construction purposes which pollutes the atmosphere and degrades the land, deforestation especially for fuel, settlement development and bush burning as a bad farm practice. These activities are assumed to be the cause of the changes in climatic trends in the district.

From figure 4, the mean rainfall for the period 1986-1990 was 109.4, 107, 125.8, 116.6 and 60.3 respectively. The coefficient of determination ($R^2 = 0.1837$) indicates that approximately 18% of the model showed a decreasing trend of rainfall in the wet season.

The year 1988 recorded the highest rainfall with the Wet season recording the highest amount of rainfall. The year 1990 recorded the least amount of rainfall for the five year period with the Harmattan season recording the lowest. None of the values recorded for the year 1990 exceeded the mean of 114.54 mm for the 30 year period. Observing the rainfall patterns over the five years, we can conclude that the rainfall trends have generally been irregular with some years increasing and others decreasing.

Figure 5 shows rainfall trends from 1991-1995. In 1991, the maximum rainfall was 307.6mm which was recorded in the month of

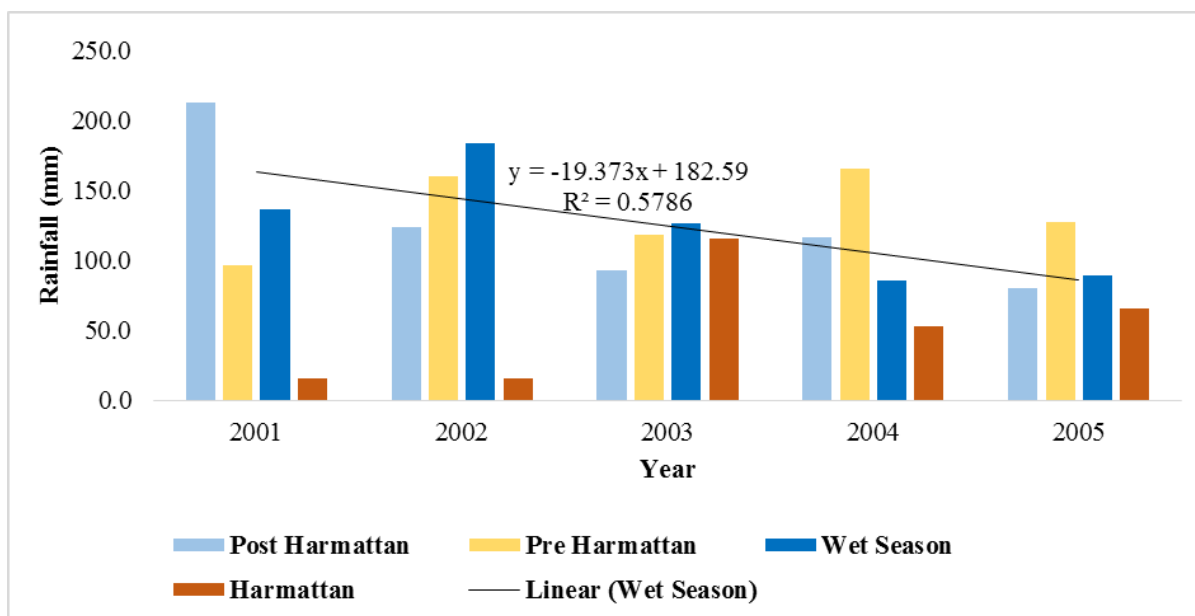


Figure 7 Graph showing composite Rainfall trends for the seasons from 2001-2005

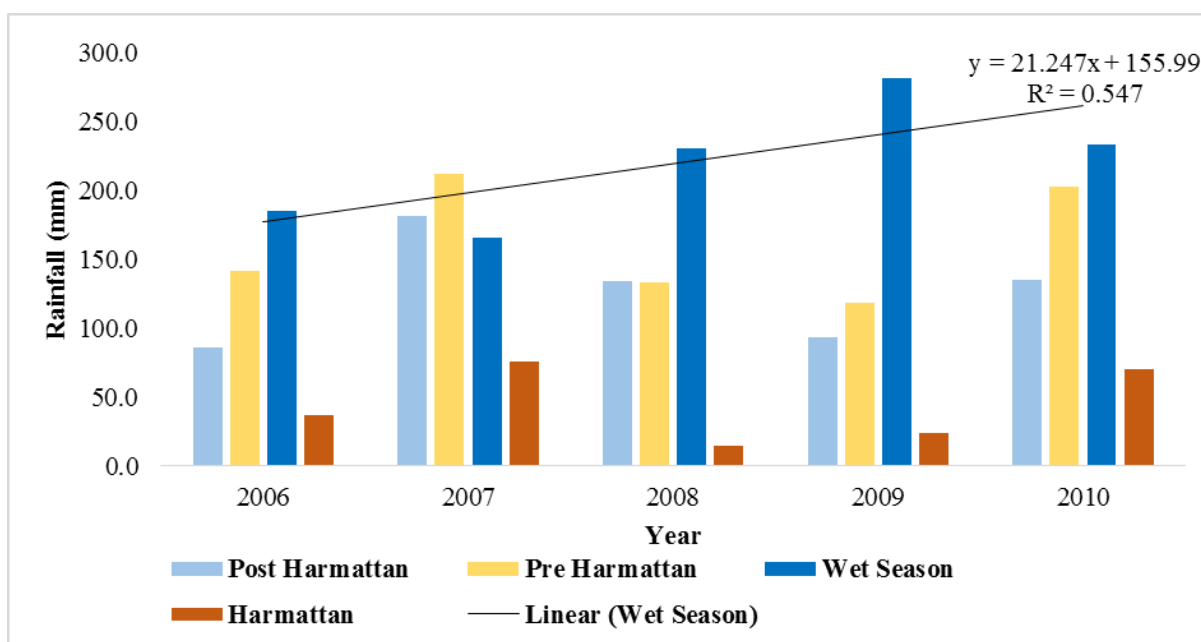


Figure 8 Graph showing composite Rainfall trends for the seasons from 2006-2010

May in the Wet season whereas the Harmattan season in the month of December had the least amount of rainfall of 8.7mm. The mean rainfall recorded for 1991 was 105mm. Most of the values recorded for rainfall were not too close to the mean for the 30 year period which is 114.54mm. For the year 1992, the Pre-Harmattan season recorded the highest rainfall of 309.9mm in the month of September whereas the Harmattan season had the least amount of rainfall. 1993 showed the least amount of rainfall among the 5 year data set of which none of the months for that year exceeded 150mm with the mean rainfall being 59.9mm.

By observation, there was a drastic change in the rainfall patterns leading to an increase in rainfall trends for the year 1994 which is actually the highest for the 5 year period with the Wet season having the highest amount of rainfall (311.8mm) in the month of May with the mean rainfall for the year being 117.1mm. This showed a great increase in rainfall amounts from the previous year. The coefficient of

determination ($R^2 = 0.0312$) indicates that approximately 0.3% of the model showed a decreasing trend of rainfall in the wet season.

1995 showed a slight change in rainfall patterns, whereas certain months had an increase, others decreased but the month of October which is the Pre-Harmattan season had the highest amount of rainfall of 226.5mm. This data set confirms the rainy season characteristics described by farmers in the districts as being occurring between the Post-and Pre-Harmattan seasons (April and October). The reason for the low rainfall patterns in December as explained by the farmers was due to the Harmattan season.

Figure 6 shows rainfall patterns from 1996-2000. The mean rainfall for each of the years was 93.4, 91.6, 117.8, 123.4, and 81.8mm respectively. From this, it can be concluded that the year 2000 had the lowest amount of rainfall whereas 1999 recorded the highest rainfall. From observation, it can be said that there a decrease in rainfall trends from 1996-1997 and an increase from 1998-1999 and a drastic fall in

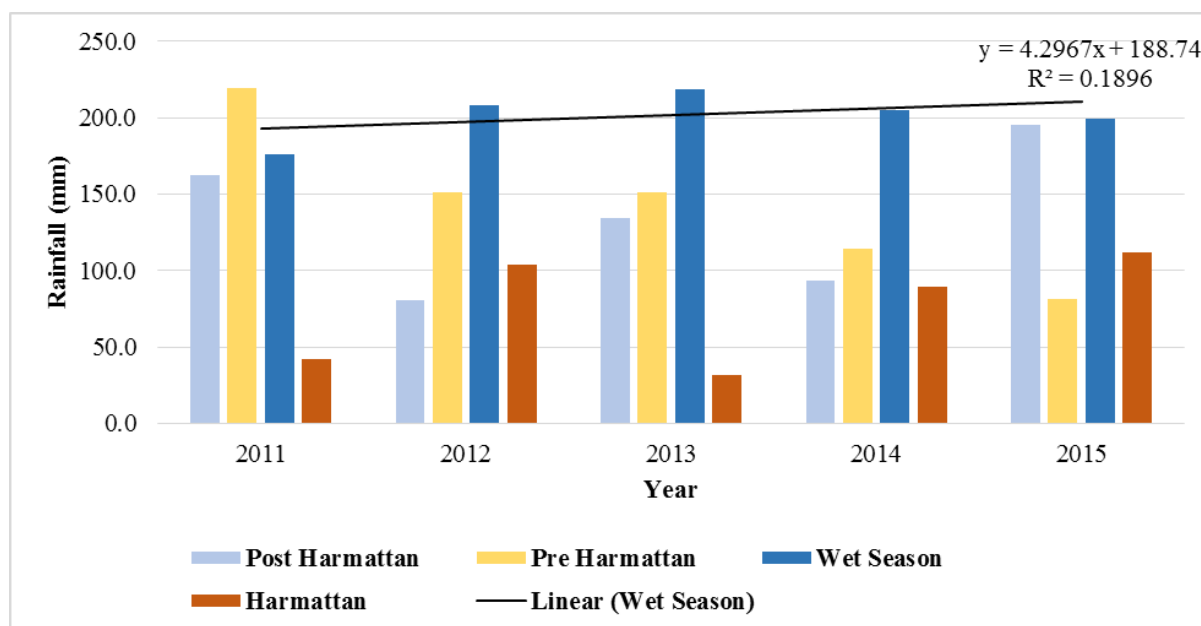


Figure 9 Graph showing composite Rainfall trends for the seasons from 2011-2015

Table 2 Results for MAKESENS Rainfall Trend Analysis

Time series	First year	Last Year	N	Test Z	Signific.	Q
January	1986	2015	30	0.32		0.064
February	1986	2015	30	1.21		1.216
March	1986	2015	30	0.43		0.675
April	1986	2015	30	0.84		1.154
May	1986	2015	30	2.02	*	3.695
June	1986	2015	30	1.59		3.413
July	1986	2015	30	0.45		0.804
August	1986	2015	30	-0.34		-0.262
September	1986	2015	30	0.20		0.563
October	1986	2015	30	1.62		3.145
November	1986	2015	30	2.11	*	2.933
December	1986	2015	30	-1.18		-0.378

*, ** and *** trend is significant at 0.05, 0.01 and 0.001 respectively

rainfall in the year 2000. $R^2 = 0.0117$ which indicates that approximately 0.1% of the model showed a decreasing trend of rainfall in the wet season. In conclusion, rainfall trends over the years have not been regular but fluctuating and unpredictable. The reason for this as explained by the farmers was mainly as a result of human land use activities that have altered the environment.

Analyzing the years 2001-2005, the mean rainfall for each of the years was 115.5, 121.1, 113.6, 105.4 and 90.8 respectively. It can be seen from figure 7 that the year 2005 had the lowest amount of rainfall whereas 2002 recorded the highest rainfall in the Wet season. From observation, it can be said that there has been a general decrease in rainfall patterns from 2001-2005 especially from 2003-2005 recording the lowest for the five year period. $R^2 = 0.5786$ indicates that approximately 58% of the model showed a decreasing trend of rainfall in the wet season. In conclusion, rainfall trends over the years have been irregular and unpredictable. The reason for this as explained by the

farmers was mainly a as a result of anthropogenic causes that have altered the way the ecosystem operates.

Figure 8 indicated that in 2006, the maximum rainfall was 280.2mm which was recorded in the month of October (Pre-Harmattan season) whereas the Harmattan season recorded the least amount of rainfall of 4.8mm in the month of December. The mean rainfall recorded for 2006 was 112.5mm. The values recorded for rainfall in 2006 was below the mean for the 30 year period which is 114.54mm. This was the lowest rainfall pattern recorded for the 5 year period. For the year 2007, the Pre-Harmattan season recorded the highest rainfall whereas January had the least amount of rainfall of 3mm in the Harmattan season, with an annual mean temperature of 159mm.

The data set is not too close to the 30 year mean of 114.54mm. 2008 had a mean rainfall recording of 128.4mm with the month of January, which is the Harmattan season, recording the least rainfall whereas the Wet season in the month of May recorded the highest rainfall of

344.3mm. In 2009, the mean rainfall was 129.5mm with the Wet season recording the highest amount whereas the Harmattan season recorded the lowest. 2010 recorded the highest rainfall for the 5 year period with a mean temperature of 160.5mm. The Wet season recorded the highest rainfall during the five-year period. Also, the coefficient of determination which is $R^2 = 0.547$ indicates that approximately 55% of the model showed an increasing trend of rainfall in the wet season.

The mean rainfall for the year 2011-2015 was 150.2, 136.2, 133.9, 125.8 and 147.9mm respectively, all of which are above the mean for the 30 year period which is 114.54mm. During the five year period between 2011 and 2015, figure 9 shows that the year 2011 recorded the highest rainfall whereas 2014 recorded the lowest amount of rainfall. There was a general decline in rainfall patterns in the five year period with the exception of 2015. $R^2 = 0.1896$ indicating that the model explains approximately 18% of the response data around the mean showed an increasing trend. From the graph above, it is obvious that the months of April-June and September-November are the major and minor rainy seasons respectively since these months recorded the highest amount of rainfall. Also, January, August and December which recorded the lowest amount of rainfall, corresponded with the dry seasons per the data in Fig 9.

Analysis of rainfall trend spanning 1986-2015

Table 2 shows a summary of the results for the 30-year period for rainfall trends. It can be observed that, May and November are statistically significant and therefore we reject the null hypothesis of each month. Whereas the months of January to April, June to October and December are not statistically significant meaning that there is no correlation between the variables temperature and years. Therefore, the Mann-Kendall hypothesis failed to reject the null hypothesis of no monotonous trend was upheld because rainfall did not show any monotonous trend, hence, we failed to reject the null hypothesis.

DISCUSSION

Results for the Mann-Kendall trend analysis showed that temperature trends did not have a monotonic trend. This depicted the temperature graphics in a series of data variability in trends. Also, results showed that Rainfall patterns are erratic; meaning as the years progress, rainfall values decreased and increased at varying and inconsistent rate. In a study of the Tanzanian Arid zone, Mkonda & He (2017) noted that the overall climate, as was explained by the temperature and rainfall, have been changing over the years under review.

An evidence of climate change could be that, temperate regions may turn out to be wetter, while dry regions may also become drier than usual. Rainstorms could also intensify and rainfall could become more and more unpredictable and inconsistent. The variability in rainfall patterns could influence soil moisture, this is important for efficient growth in crops. Temperature increase combined with reduced rainfall is likely to reduce the availability of land for crop production in an area due to increased acidity, soil moisture loss, increased salinity as well as groundwater depletion (Chijioke et al. 2015).

Looking critically at the historical climatic data of Ghana, there was high rainfall in the 1960s but this declined in the latter part of 1970s and early parts of 1980s. The drastic decline in rainfall trends are still visible in recent years, a 20 year data detected that, there is a rising trend in temperature of all climatic zones in Ghana and rainfall have been declining and becoming more inconsistent. The effect of climate variability is calculated to be more intense despite the rise and fall in

both temperature and rainfall yearly (Asante & Amuakwa-Mensah 2014).

Observing temperature trends for the year 1986-2015 for the study districts using the Mann-Kendall trend analysis, it can be seen that temperature trends among the months for the 30 year period do not show a regular pattern. Whereas the months January, February, March, April, May, November and December are experiencing a decline in temperature, the months June, July, August and September are experiencing an increase in temperature.

The causes of climate variability per the information received indicated that anthropogenic activities are the main causes of these variations. These activities include; increased sand winning for construction purposes which pollutes the air and degrades the land, deforestation especially for fuel, settlement development and bush burning as a bad farm practice. These activities are assumed to be the cause of the changes in climatic trends in the district.

Looking at the data set from 1996 to 2016, there is no monotonic trend in rainfall patterns. They fluctuate over the years. This confirms that there are variations in the rainfall patterns as observed in the temperature trends. However, it is a fact that rainfall is higher during the wet seasons and lower in the Harmattan season.

Just like the case of temperature, rainfall patterns have been erratic mainly due to anthropogenic activities in the region; and these have altered the natural recycling of moisture from the soils through the trees into the atmosphere from where it returns as rainfall. Among these activities are; development of settlement, sand winning for construction purposes, deforestation for charcoal production and wood processing.

These erratic patterns have serious implications on water availability on the Dam, household water supply as well as groundwater (Momodou Badjie et al. 2019). According to a study conducted by (Toure et al. 2017), groundwater storage is decreasing mainly due to climate change effect and human activities. This resulted in reduced groundwater recharge and threatens the future availability of fresh water for consumption. Also, erratic rainfall patterns may affect the level of water in the Owabi dam and consequently the availability of water for domestic and industrial use.

A study conducted by Amikuzuno & Donkor (2012) showed that in Ghana, rainfall variations are a threat to the productivity of smallholder farmers. In recent years, crop failure as a result of inconsistent rainfall patterns have generally been due to late rains for planting, variability in the pattern and levels of rainfall, droughts and floods. This makes climate variability a problem especially in Ghana.

CONCLUSION

The study has shown the erratic patterns of temperature and rainfall, as indicated from the Mann-Kendall trend analysis. The results have shown that rainfall trend is reducing with time, however it has become difficult to predict the rate and volume of the reduction, due to the inconsistencies recorded over the thirty-year period; particularly in the latter decades. The intra-annual rainfall patterns also concurred with the seasonal dis-aggregation of the years into Post-harmattan, Pre-harmattan, Harmattan and Wet seasons. With prolonged Harmattan seasons, rainfall onsets and cessation are difficult to predict.

This paper indicates that the changing trends of the climatic variables *per se*, are not sufficient conditions for predicting climate change; however, the inter-seasonal behaviors of the climatic variables complement the necessary conditions of establishing a climatic variability and change at a local, sub-national to national and sub-regional scale. There is the need to analyze trends in temperature and

rainfall in order to put in measures to properly adapt to the changing trends of climate. This implies that water budgeting for various applications from agriculture, domestic and commercial uses, should take into cognizance the changing patterns of the climatic variables (temperature and rainfall) in the study region.

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