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Analysis of Rainfall and Temperature Trend and Variability of the Tordzie Watershed in Ghana

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ABSTRACT

Climate change is universally occurring but probable fluctuations are not anticipated to be uniform worldwide; rather, there may be local differences. Thus, there is a need to investigate the trend and variations at the local and watershed levels to comprehend the magnitude of the change. This study was conducted to determine the trend of rainfall and temperature and assess their dependability. In this study, mean monthly and annual rainfall and temperature were analysed to determine the variability in magnitude over the period 1984-2014 at different stations. The non-parametric trend detector, Mann-Kendall test (MK) and trend magnitude detector, Sen's Slope (SS) were used to reveal the trend and magnitude of rainfall and temperature, respectively. The largest increasing slope of significant annual precipitation occurred in November with a magnitude of 1.68 mm/y in Tordzinu. October recorded the most reliable rainfall at Kpetoe with a Coefficient of Variation (CV) of 0.3. The highest maximum monthly rainfall occurred in May, 2005 at Tordzinu with a magnitude of 522.2mm for the period under review. The minimum and maximum temperature increased by 0.2°C and 0.8°C respectively at Kpetoe and also 0.2°C and 0.5°C at Tordzinu per decade respectively.

Keywords: *climate, rainfall, temperature, trend, variability, Tordzie Watershed*

INTRODUCTION

Climate change is the variation in statistical characteristics of the climate system over an extended period irrespective of the grounds of this change (IPCC, 2014). According to Finnis *et al*. (2015), the earth is heating up as a result of human activities. The authors further reported that there is irresistible scientific evidence on increasing temperature. IPCC (2014) revealed details of the startling devastating effect of climate change on diverse sections of the economy. Agriculture, water resources, human wellbeing, ecosystem and biodiversity were impacted by climate variability and change (IPCC, 2014). Thus, there are calls for an understanding of the variation of climate in both space and time within a zone or watershed of a locality. The relationship between factors and activities related to climate change ought to be examined as well. Rainfall is an important factor affecting crop selection and ecological changes in a region (Ahmad *et al*., 2015).

Yao *et al*. (2014) and Hay *et al*. (2011) reported that the hydrological cycle is predicted to be impacted by climate change through alterations in precipitation. Besides the authors suggested that precipitation is the primary driver of unpredictability in the water balance through an altered pattern of rainfall and its intensity. Also, Hay *et al.* (2011) stated that evaporation and transpiration by plants will be altered as a result of climate change with hydrological implications. In their study, Arnell *et al*. (2015) established that fluctuations in discharge from year to year is highly correlated to rainfall variations than to temperature fluctuations. Hay *et al*.(2011) and Arnell *et al*. (2015) further stated in their research that climate variation inclines to affect the magnitude of discharge for mild temperate climates, in diverse seasons by a quantity that is influenced by the change in rainfall, with monthly variability being greater than annual variability.

Yosef *et al.* (2015) stated that rainfall (rainfall frequency, rainfall intensity and rainfall amount) governs crop yield and limits the type of crop that can be grown and for that matter, its seasonal/annual variability could affect crop productivity adversely. Thus the frequency of dry spells and droughts exacerbate the incidence of crop failure. In a related study, Molina-Sanchis *et al*. (2016) suggested that the timing and quantity of rainfall are among the most essential variables that impact agriculture. Molina-Sanchis *et al*. (2016) therefore, emphasised the analysis of long historical records of rainfall since it offers help on rainfall pattern and variability. There is therefore the need for scientific analysis and evaluation of the climatic data to assist farmers who are engaged in rain-fed farming.

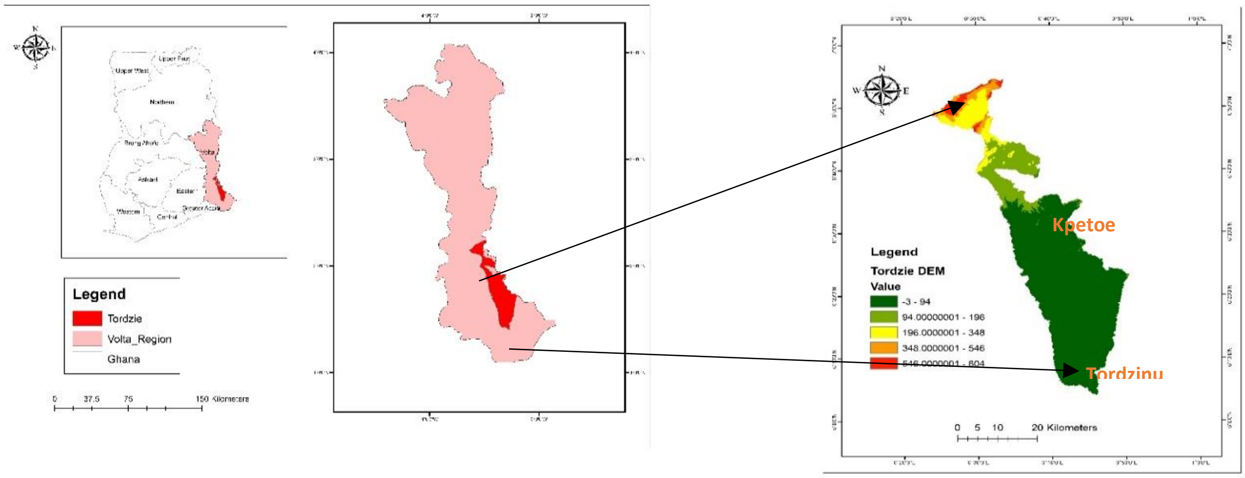
Due to the variability of rainfall from season to season, the criteria for planning water supplies cannot be based on average rainfall. The rainfall for these purposes needs, therefore, to be based on probability or frequency analysis. According to Hag-elsafi and El-Tayib (2016) concepts of probability are generally used in comprehending the rainfall pattern and analysis of probabilities of events, which Gebremichael (2014) claimed follow particular types of distributions. Similarly, Alam *et al*. (2018) reported that the theory of normality of rainfall distribution is one of the most essential and commonly employed analyses.

In this study, historical rainfall records were analysed and their future occurrence and probability of the rainfall events carried. Temperature analysis was also conducted. Also, statistical tools such as the Mann-Kendall test and Sen’s slope were employed to characterise the rainfall trend and its magnitude respectively. The assumption was that the historical and future data sets were correlated. The expectation is that future time series will reveal frequency distributions similar to the observed one.

MATERIALS AND METHODS

Study Area

Tordzie watershed is a transboundary basin, the area in Ghana constitutes 83.7% and the remaining area in Togo is 16.3% (WRC, 2010). The geocodes of the chosen stations were Kpetoe (6˚54'0"N, 0˚69'0"E) and Tordzinu (5˚5'0"N, 0°45'0"E) at altitude 79.0 m and 5.4 m respectively. The catchment area of the watershed under consideration is 1278 km^2. Figure 1 illustrates the Tordzie watershed. The Tordzie watershed in Ghana was chosen for the study with particular stations. The data for the analysis was obtained from different meteorological stations spanning diverse geographic locations. The choice of the stations were based on data availability.



(a) (b)

Figure 1: Map of Ghana Showing (a) Volta Region, Tordzie Watershed and (b) Digital Elevation Model of Tordzie Watershed (Source: generated from field data2017).

Climatic Conditions

The study area spans the northern and the middle (transition) belt of Ghana. The climate of the study area is described as dry Equatorial. Tordzie watershed has a semi-deciduous forest in the northern part. The entire outlet of the watershed has equatorial climatic conditions. The watershed has two rainfall seasons. The major rainfall occurs between April and June and the minor one between September and October. The annual average rainfall is 980 mm and the corresponding average maximum temperature is 30 ^{o}C. June is the month with the usual high rainfall amount in the area (Amekudzi *et al*., 2015, Aryee *et al*., 2017).

Tordzie basin has annual rainfall that varies from 1400 mm in the north to about 910 mm in the south. The rainfall in Tordzie is double maximum. The major rainfall occurs between March/April to July and the minor one between September and October. It is only during the rainy season that low rainfall contributes to stream flows (Nyatuame *et al*, 2020). The smaller streams or tributaries that contribute to recharging the Tordzie basin dries up between November and April. It is recorded that the Tordzie basin dried up at its lower reaches into a series of pools.

Study Methods

Quantitative secondary data of both rainfall and temperature were obtained from Ghana Meteorological Agency (GMet) for analysis. The rainfall data were organised and tabulated in Excel, then XLSTAT, 2018 software was employed for the analysis. The data gaps were filled using linear interpolation. Mann-Kendall test (Mann, 1945; Kendall, 1975) was used to analyse the trends in rainfalls for all the stations using the monthly data for the period spanning from 1984 to 2014. The results were presented in graphical forms using Minitab and Excel. The test was to establish whether or not a statistically significant decreasing or increasing trend or none could be found in the data set. Besides, frequency analysis and the return period of the various events were computed using the respective equations. Besides the mean, standard deviation, extreme values (minimum and maximum values) and skewness were determined. The moving average at 5 years (half decadal) interval was computed and time series of the monthly and annual data were plotted. Anderson-Darling's (AD) goodness-of-fit test was used. This value measures how well the data represents a precise distribution. A smaller value indicates a good fit for data distribution. To test whether the data belongs to a particular distribution the corresponding p-value was used. The null hypothesis of the data representing a particular distribution is not accepted if the p-value is smaller than 0.05. The best fit corresponds to the p-value of the highest magnitude. For the same p-value, the best fit is decided by the smallest AD value. The methods of analysis that were used in this study have been explained in the following sections:

Frequency Analysis
Analysis of the probable occurrence of climatic events especially rainfall was done using scientific tools such as frequency of occurrence of the events. It is a tool employed in design rainfall determination. Besides, it is essential in determining design hydraulic capacity relating to stream flow, drainage works and drainage structures. The Weibull ranking method was used as follows;

$F=\frac{100\,m}{n+1}$ Goyal (2016) (1)

Where: F is the frequency of occurrence; m is the rank quantity and n is the entire quantity of values in the data set.

Return Period
The term return period, also called the recurrence interval of any hydrologic event, is the mean time that passes between two events that equal or exceeds a particular level and it is measured by the formula in Equation 2.

$\boldsymbol{T=\frac{1}{f}}$ Chow (2010) (2)

Where: T is the return period in years and f is the frequency of occurrence of a hydrologic event.

Probability of Occurrence
The probability p of an n-year event of return period T is

$\boldsymbol{P=\frac{100}{T}}$ Chow (2010) (3)

Statistical Analysis
The statistical measures that were used for analysis in this research work are described as follows (Equations 4 to 8):

Arithmetic Mean
The arithmetic mean, represented as $\bar{X}$, of a set of n quantities x_1, x_2 ------x_n is defined as the sum of the quantities divided by n. In statistics, the arithmetic mean is normally employed as the single value representative of a set of data. The formula for arithmetic mean is:

$\bar{X}=\frac{x_1+x_2+---x_n}{n}$ (Ayyub & McCuen, 2016) (4)

Standard Deviation
Standard deviation is a measure of variability that is based on all the data in a set. Standard deviation is also described as the square root of variance. The formula for evaluating variance is shown in Equation (5).

$S^2=\frac{\sum_{i=1}^{n}(X-\bar{X})^2}{n-1}$ (Ayyub & McCuen, 2016) (5)

$\delta=\sqrt{S^2}$ (Ayyub & McCuen, 2016) (6)

Where, S^2 = variance, δ =Standard deviation, x = variable, n= number of variable, $\bar{X}$=mean

Skewness
Skewness is defined as the lack of symmetry of a distribution. The expression for coefficient of skewness is given as

$C_s=\frac{a}{\delta^3}$ (Ayyub & McCuen, 2016) (7)

Where,

$a=\frac{n}{(n-1)(n-2)}\sum_1^n(x_i-\bar{x})^3$ (Ayyub & McCuen, 2016) (8)

Minimum
This refers to the minimum value out of a given set of variables.

Maximum
Maximum refers to the highest value out of a given set of variables. It was gotten by comparing all the variables in the set and picking the one with the highest value.

Trend Analysis
Mann-Kendall (MK) Analysis

For instance the time series of n data sets with T_a and T_b being two sub-sets of the same data set. Where: a=1,2,3---,n-1 and b=a+1, a+2, a+3,---n.

The data set T_a as a reference set was compared with all the T_b data points such that:

$$Sign(T) = \begin{pmatrix} 1 for T_b > T_a \\ 0\, for T_b = T_a \\ -1 for\ T_b < T_a \end{pmatrix}$$ (Mann, 1945; Kendall, 1975) (9)

The Kendal test's S-statistic was compared as:

$$S=\sum_{a=1}^{n-1}\sum_{b=a+1}^{n} sign(T_b - T_a)$$ (Mann, 1945; Kendall, 1975) (10)

The variance for the S-statistic is defined as:

$$\delta^2 = \frac{n(n-1)(2n+5)-\sum_{a=1}^{n} t_b(a)(a-1)(2a+5)}{18}$$ (11)

where t, represent the number of ties to extent a. The Z_s denoted as the test statistic was computed as:

$$Z_s = \begin{Bmatrix} \frac{s-1}{\delta}\ for\ s > 0 \\ 0\ for\ s = 0 \\ \frac{s+1}{\delta}\ for\ s < 0 \end{Bmatrix}$$ (Mann, 1945; Kendall, 1975) (12)

The significance of the measured trend is denoted as Z_s. If Z_s is larger than $Z_{\alpha/2}$, then the null hypothesis is invalid, where α denotes the chosen level of significance (5 %, with $Z_{0.025}$), indicating the trend is significant. An independent and arbitrarily ordered data set in Mann- Kendal test is regarded as the null hypothesis. Mann – Kendal test does not request normality. The MK only provide direction but not the magnitude of significant trends. The implication of Equation (9) is that if T_a is greater than T_b the value of T will be 1, and the second condition shows that if T_a is less than T_b the value of T will be -1, while the last condition implies that if T_a=T_b, then the value will be 0. MK analysis has a bottom-up approach because the reference point is being compared with all the T_b values above.

Sen's Slope method

The procedure of Sen's slope was employed to determine the change rate as:

$$\delta = median\left(\frac{X_b - X_a}{b-a}\right) \quad a < b$$ (Sen, 1968) (13)

Where X_b and X_a are the data values in times b and a respectively. The symbol δ denotes the trend of change and the magnitude of the value characterises the gradient of change. The slope estimated by Sen's slope estimator is a strong estimation of the magnitude of the trend (Gocic and Trajkovic, 2013).

Moving Average

The moving average smoothing technique takes the mean of the k most current data values to forecast the value of the sequence for the succeeding period in the future. A moving average of order k, MA (k) is calculated as:

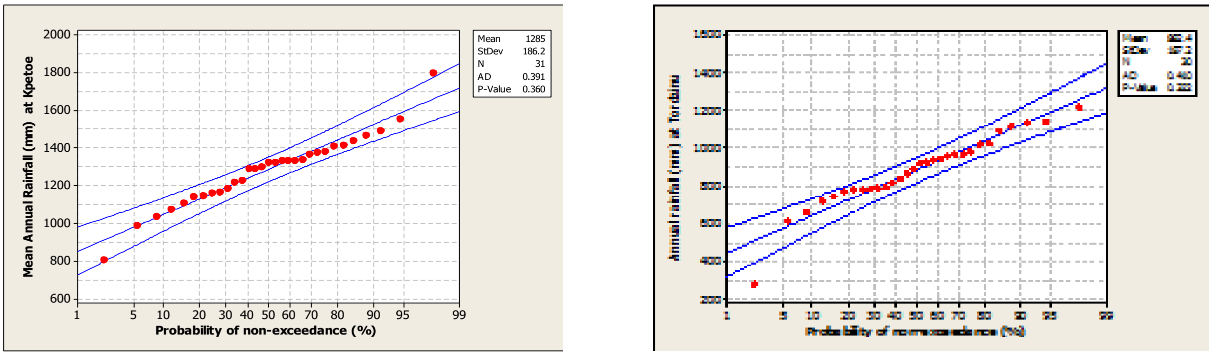
$$F_{i+1} = \frac{\sum_{i=1-k+1}^{t} Y_i}{k} = \frac{Y_t + Y_{t-1} + Y_{t-2} + --- Y_{t-k+1}}{k}$$ (Ayyub & McCuen, 2016) (14)

Where F_{i+1} is the forecast for period t+1, Y_t is the actual value for period tk is the order of the moving average

RESULTS AND DISCUSSION

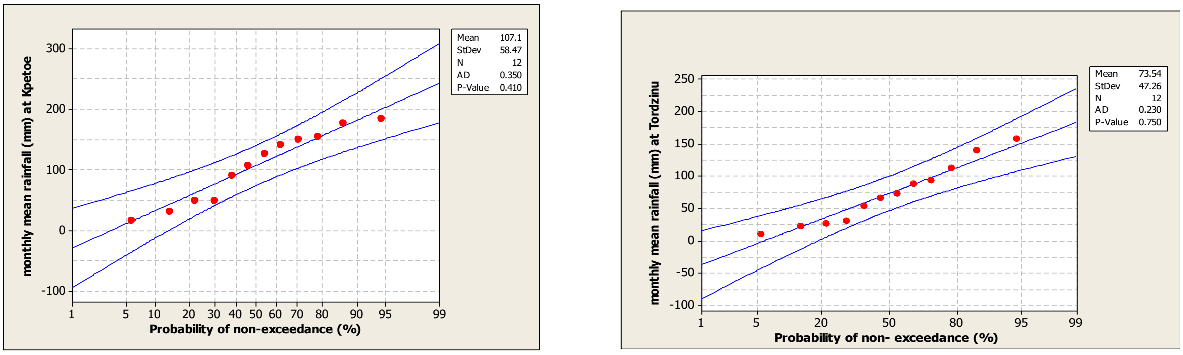
Frequency and Probability Analysis

The results of the analyses for Kpetoe and Tordzinu which are stations in the Tordzie watershed are displayed in graphs and tables. For example, the probability of non-exceedance for Kpetoe and Tordzinu for both annual and monthly rainfall is shown in Figure 2 (a and b) and Figure 3 (a and b), respectively. The probability plot provides the probability of occurrence and non-occurrence of different annual rainfall magnitude from which the corresponding return period was computed and dependable rainfall determined. Dependable rainfall is vital to rain-fed agriculture and provide the likely or probable risk associated with dry farming. This information is useful to farmers.



(a)
(b)

Figure 2: Probability of non-exceedance of annual rainfall at (a) Kpetoe and (b) Tordzinu



(a) (b) o

Figure 3: Probability of non-exceedance of monthly rainfall at (a) Kpetoe and (b) Tordzinu

From the fitted line (Figure 3), any probability of non-exceedance and exceedance of a certain amount of rainfall can be derived. The distribution of the rainfall may however be skewed. Skewness in rainfall analysis normally means that there is a relatively high frequency of amounts below the mean being compensated by a relatively small number of high precipitations. This skewness may be caused by the unusual distribution of rainfall or biased data or data set being few. In general, for most agricultural purposes probabilities below 80 % and over 20 % are used. The value of the Anderson-Darling (AD) goodness of fit test and associated p-values are presented alongside the graph.

The 20 % dependable rainfall (P_{20} = 0.20) has a return period of (1/ (0.20) =) 5 years. That is on average once every 5 years the annual rainfall in the Tordzinu will be equal to or larger than 1039.95 mm in the year (Figure 4). The 50 % dependable rainfall has a return period of 2 years, or on average once every 2 years the rainfall depth will be equalled or exceeded.

Table 2: Probabilities and return periods of annual rainfall for Kpetoe and Tordzinu

Estimated Annual Rainfall (mm)-Kpetoe	Estimated Annual Rainfall (mm)-Tordzinu	Probability of Exceedance (%)	Return Period (year)
1046.19	642.539	P_{90}	1.11
1128.12	724.88	P_{80}	1.25
1187.20	784.26	P_{70}	1.43
1237.68	834.99	P_{60}	1.67
1284.86	882.42	P_{50}	2
1332.04	929.84	P_{40}	2.5
1382.53	980.57	P_{30}	3.33
1441.60	1039.95	P_{20}	5
1523.54	1122.30	P_{10}	10

The results revealed that the probability of exceedance of various quantities of rainfall for the stations decreased with an increase in the exceedance probability as the threshold rainfall upsurged. As an illustration, there was at least a 90 % likelihood of obtaining annual rainfall equal to or higher than 1046.19 mm during the year in Kpetoe and 642.539 mm in Tordzinu during the year within a return period of about 1 year (Table 2). The risk associated with not having the various amount of rainfall is indicated as the probability of non-exceedance.

However, the chance of having equal or more than 1523.54 mm and 1122.30 mm during the years in Kpetoe and Tordzinu, respectively, was only 10%; with a return period of 10 years. The implication is that the risk associated with the expectation of the aforementioned amount of rainfall is 90%. The inference is that the rainfall amount is highly unreliable (not dependable). It can be concluded that more rain is to be expected from Kpetoe than Tordzinu (Table 2). These differences can be attributed to the climatic characteristics or geomorphology of the catchment area.

Analyses of the probability of exceedance and return periods project when a given amount of rainfall would be equalled or exceeded with time. This information serves in advising farmers on crop selection in tandem with its water requirements during the growth cycle and optimize on soil water conservation technologies (Mzezewa, 2012). Muita (2013) in his study conducted in Kenya defined reliable rainfall as that annual rainfall with an exceedance probability of 80% for highland farmers. Taking into account his assertion, a rainfall >1128.12 mm in Kpetoe and >724.88 mm in Tordzinu is not a reliable rainfall. Thus, comparing the above threshold with the historical annual totals the dependable rainfall years can be obtained. For application in design, it is assumed that future probabilities of an exceedance will be the same as past probabilities.

Exceedance probability application for design

The use of the probability of occurrence or recurrence interval in water-related project design is to minimise the risk associated with storm events. In designing irrigation infrastructure and irrigation operation management, dependable rainfall information is a prerequisite for effective management. According to Leela Krishna *et al.*(2018), rainfall depths that are exceeded in 3 out of 4 years or 4 out of 5 years during the peak period are used as design rainfall. The above corresponds to exceedance probabilities of 75% and 80%. For high valued economic crops, dependable rainfall of 9 years out of 10 years is advisable to be used. The application of 90% dependable rainfall in design project estimation implies lower risk but with a higher cost of irrigation infrastructure in terms of large canals or larger pipes. The design rainfall is thus an economic parameter that must be optimised considering the benefits and costs. Water conservation and harvesting structures are designed based on the important information of the probability of exceedance of rainfall at the specific site/location. According to Adham *et al*. (2016) for the efficiency of water harvesting structures, the design and its construction should be proportional to the expected amount of rainfall event.

Probability of exceedance application for planning

The planning and management of diverse water projects rely on anticipated rainfall depths. Makanjuola (2018) used the following rules for the determination of dry, normal and humid weather conditions: If the rainfall in a locality is exceeded 4 out of 5 years or having a probability of exceedance of 80% the weather condition in the locality is termed dry. A locality is having a normal rainfall if its rainfall is exceeded 1 out of 2 years or having an exceedance probability of 50%. An area is described as humid if its rainfall is exceeded 1 out of 5 years or having an exceedance probability of 20%.

Table 3: Classification of the weather (rainfall) over the Tordzie watershed

Type of weather	Probability of exceedance (%)	Tordzinu Rainfall (mm)	Kpetoe Rainfall (mm)
Dry weather	80	724.88	1128.12
Normal weather	50	882.42	1284.86
Humid weather	20	1039.95	1441.60

Thus, the years can be classified as dry, normal or humid years, respectively, based on Table 3. Table 4 presents also the rainfall distribution at 80% probability for all the network stations.

The highest monthly mean rainfall at Kpetoe on Tordzie watershed was in June with the probability of exceedance of 5.64.5 % with a magnitude of 185.5 mm and a return period of about 17 years and the other months with their respective mean rainfall, probability of exceedance, 80 % dependable rainfall and the return period can be seen from Table 4. From the foregoing, it can clearly be understood that the mean monthly rainfall in Kpetoe catchment area on the Tordzie watershed in ten (10) months was greater in magnitude than that of Tordzinu catchment area on the basin. It was only in May and November that the rainfall in the latter exceeded that of the former. From Table 4, the 80 % dependable rainfall onsets from February to December.

May is the month with the highest amount of rainfall (158 mm) with the probability of 5.6 % occurrence with a risk margin of about 94.4 % (probability of non-exceedance) at Tordzinu. Assuming that there is no change in the factors which are causing rainfall, based on available records, a prediction is made on rainfall probability in the future or the depth of rainfall that can be expected. However, rainfall rarely fully satisfies statistical theories on which the methods are based. For example, the highest rainfall at Tordzinu on the Tordzie watershed which occurred in May with a mean magnitude of 158 mm has a return period of about 17 years. It is evident from Figures 2, 3 and Table 2 that probability dwindled as the monthly rainfall threshold augmented. It is also observed that the rainfall regime is bimodal. Table 4 revealed that 80% rainfall probability starts from March in Tordzinu with a minimum value of 31 mm and ends in November with a magnitude of 28 mm. The low rainfall for the said portion of the watershed has implications for runoff volume generated and ultimately the basin discharge.

Given the above analysis, any crop (e.g. maize) planted in November-March will experience water stress due to low dependable rainfall and probably high evaporative losses. The probability of crop failure is very high in the aforementioned months. The advice to farmers is that they should cultivate the land between April to July and September to October to minimise the risk of crop failure.

Dependable Rainfall Application for crop production

Rainfall amount and its variability is vital information for deciding on the choice of crop to grow and when to start planting. A knowledge of monthly rainfall distribution is vital as it informs one on how much moisture (water) is available for the production of crops in the case of dry farming. If the threshold for dry farming is determined, it then becomes the benchmark for comparison. Also, rainfall amount during the growing season is crucial for the crop to give the optimum yield. According to Sutcliffe *et al*. (2016), maize requires an optimum rainfall between 500 mm and 800 mm during the growth period. The total dependable rainfall for the period of March to October at Kpetoe and Tordzinu is 709 mm and 362 mm, respectively. The probability of exceeding 800 mm annually are presented in Table 2 for the two stations. That of Tordzinu is around 60 % of exceedance. Thus, the risk is very high in producing a less drought-tolerant crop like maize in that part of the said watershed unless irrigation measures are adopted.

Annual Rainfall Trend

Figure 4 reveals an oscillatory kind of total annual rainfall trend at a moving average of half decadal at Kpetoe station. Both the actual and projected (forecasted) are erratic. Again, from Figure 4, the moving average of total annual rainfall at Tordzinu depicted not too smooth an increasing trend from the station. Besides the forecasted trend could best be described as an insignificant trend while the actual trend was highly oscillatory. The above trend or change in the time series data could be caused by climate change as a result of increased greenhouse gas concentrations or land-use changes (urbanisation, clearing of trees, deforestation, etc) or change in management practices over the catchment. The findings are largely in agreement with the results obtained by Dumenu and Obeng (2016) and Kleemann *et al*. (2017) who reported a general reduction in rainfall with marked cyclical high and low events.

Table 4: Monthly mean rainfall and probability of exceedance

	Kpetoe			Tordzinu		
Months	Probability of exceedance	Rainfall at 80% probability	Mean Rainfall (mm)	Probability of exceedance	Rainfall at 80% probability	Mean Rainfall (mm)
January	94.35	0	17.7	94.35	0	11.0
February	78.22	14	49.1	86.29	0	23.2
March	54.03	58	107.1	45.96	31	73.5
April	37.90	95	141.7	37.90	41	88.7
May	21.77	103	155.1	5.65	79	158.0
June	5.64	121	185.5	13.71	81	139.9
July	45.97	75	126.9	62.1	15	54.4
August	62.09	35	91.3	70.11	5	31.3
September	13.71	106	177.9	29.83	43	94.4
October	29.83	116	151.3	21.78	67	113.6
November	70.11	23	49.7	54.04	28	67.1
December	86.29	5	31.6	78.23	0	27.4

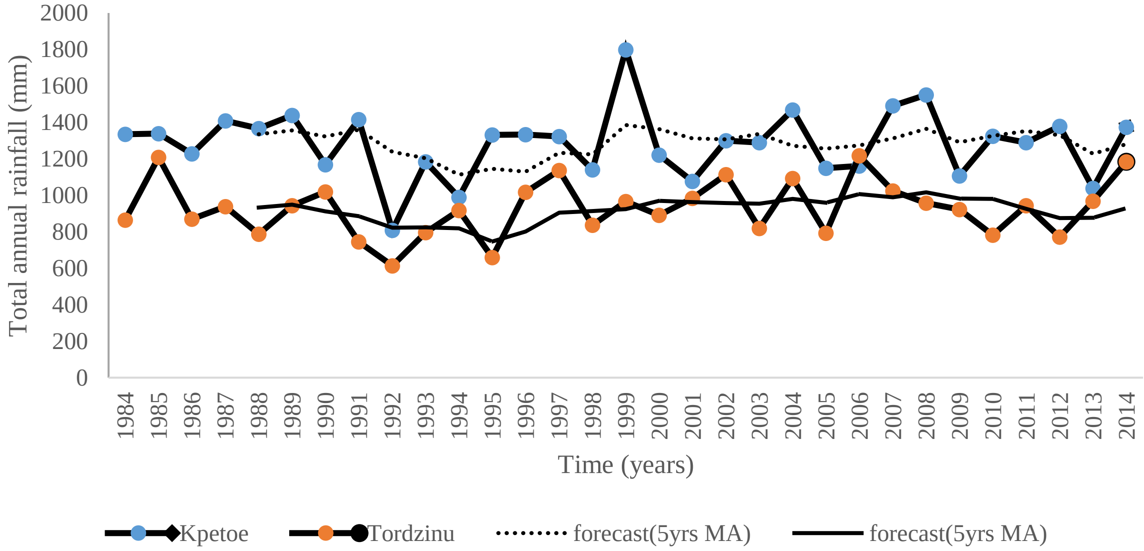


Figure 4: Five (5) years moving-average of rainfall trend

Table 5: Decadal variation of rainfall, maximum and minimum temperature

Year	Kpetoe			Tordzinu		
	Rainfall(mm)	T_{max} (^{0}C)	T_{min} (^{0}C)	Rainfall(mm)	T_{max} (^{0}C)	T_{min} (^{0}C)
1984-1994	103.7	32.3	22.0	73.5	31.8	23.5
1994-2004	108.6	32.5	23.0	79.1	32.3	23.7
2004-2014	108.1	32.6	23.2	78.9	32.8	23.8

The implication of the variability and reduction in the annual totals of rainfall amount is that rain-fed agriculture is highly risky and calls for technology interventions for crop production. Irrigation infrastructure is recommended especially micro drip and sprinkler irrigation facilities that have high water use efficiencies in addition to the breeding of drought-resistant cultivars and other mitigation and adaptation strategies.

There was an increase of 0.2^{o}C, 0.1^{o}C and 0.8^{o}C, 0.2^{o}C in maximum and minimum temperature, respectively, at Kpetoe between 1984-1994 to 1994-2004 and 1994-2004 to 2004-2014 (Table 5). Likewise for the same stated period at the Tordzinu side of the Tordzie watershed, the maximum and minimum temperatures increased by 0.5^{o}C,0.5^{o}C and 0.2^{o}C, 0.1^{o}C, respectively. The results indicated a rise in the temperature (maximum and minimum) per decade with its implications. The rising temperatures could be attributed to the conversion of vegetation to farmland and settlement as reported by other researchers (Nyatuame *et al*, 2020).

Time Series Analysis

Figure 5 revealed a fluctuating characteristic of annual rainfall in the Tordzie watershed. The rainfall depicts an irregular trend. Among the two stations, Tordzinu is more oscillatory than the Kpetoe. The higher rainfall at the Kpetoe side of the watershed compared to Tordzinu could be accredited to forests and the mountains. The low forest cover and the coastal nature of the Tordzinu could be the result of low rainfall. Since evapotranspiration generated from vegetation is a process by which water vapour is converted into rainfall. The water vapour generated from the forest in the form of evapotranspiration rises to the upper atmosphere and come back as convective rainfall. Thus the low forest leads to lower evapotranspiration and hence low rainfall (Sayama et al, 2021). However, Ibitolu *et al*. (2014) were of the view that tropical rainfall is highly variable spatiotemporally and identifying the exact cause of variabilities is difficult.

The highest maximum monthly rainfall recorded over the Tordzie watershed for the period under evaluation occurred in the Tordzinu area of the catchment in the year 2005 with a magnitude of 522.2 mm precisely in May, as can be seen in Figures 5 and 6, respectively. This extreme rainfall could be a result of climate change and variability. The implication is associated with the flood with its attendant hazards. The monthly fluctuation of maximum and minimum temperature concerning rainfall is also shown in Figure 7. The rainfall pattern depicts a double maximum.

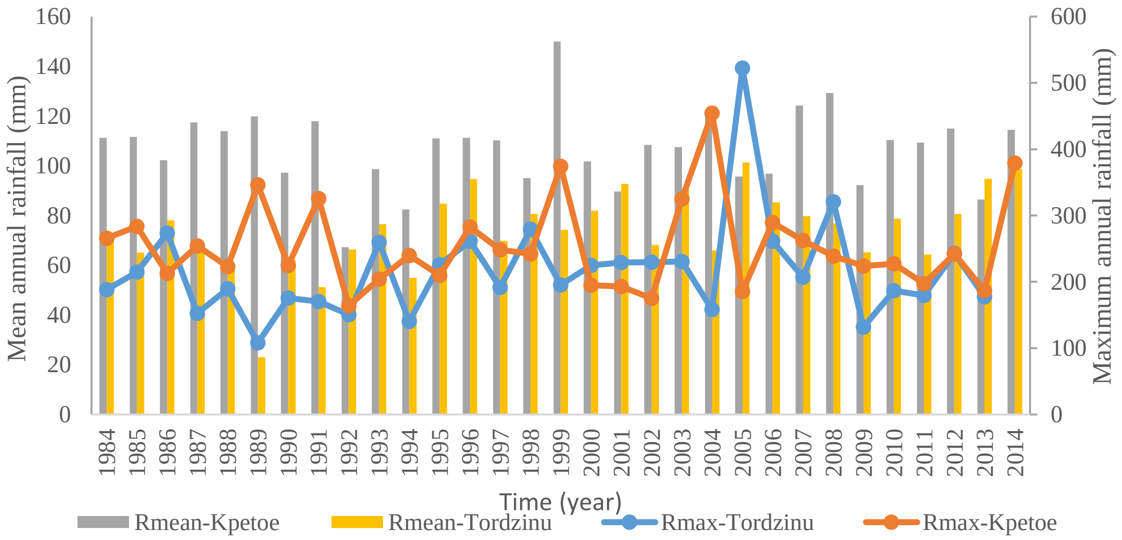


Figure 5: Mean and maximum annual rainfall variation (1984-2014)

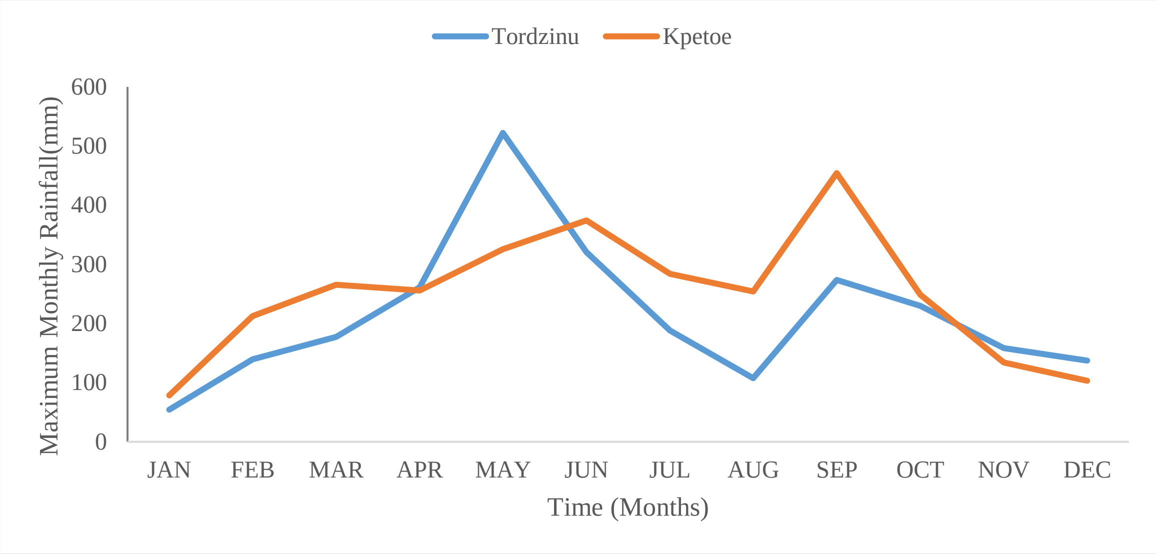


Figure 6: Maximum monthly rainfall variation

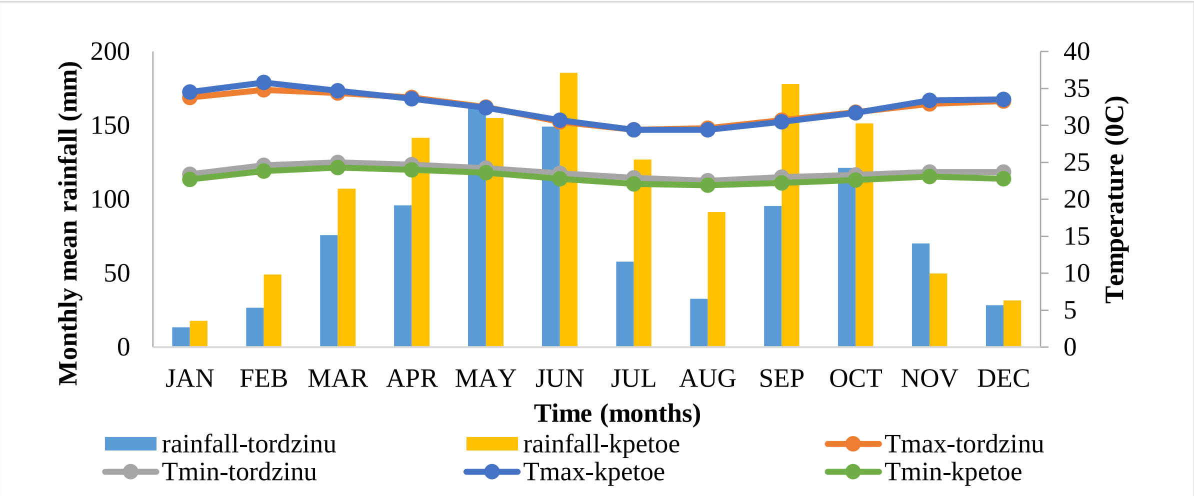


Figure 7: Monthly maximum and mean temperature and rainfall variation (1984-2014)

Monthly Rainfall Statistical Analysis

The summary of the monthly rainfall statistics at Kpetoe and Tordzinu all on the Tordzie watershed are presented in Table 6. The Coefficient of variability (CV) is used to indicate rainfall dependability/reliability or otherwise. The lower the CV of rainfall amount in any month, the lower the variability and the greater the dependability (Nyatuame *et al*., 2014). For dependable rainfall, the CV threshold is less than 50 % (0.5) (Meshram et al, 2018). The month with the most reliable rainfall is not the same at the two study stations. October recorded the most reliable rainfall at Kpetoe station with a CV of 0.3, which is in a minor rainfall season. At Kpetoe, the dependable rainfall occurred in April, May and June in the major season. On the other hand, there was no reliable rainfall at the Tordzinu side of the catchment, as CV values are above the threshold value. The shift in the rainfall distribution whereby heavy events are mostly occurring in the minor season instead of the major season is a plausible indication of climate change. This could lead to food insecurity due to the vulnerability of the small scale farmers who lack adequate climate-smart strategies to climate variability and change.

Mann- Kendall and Sen's Slope Analysis

Table 7 displays the outcomes of the Mann-Kendal trend analysis for the monthly rainfall in the two stations on the Tordzie watershed. A positive Kendall's t is an indication of an increasing trend and conversely, a negative value depicts decreasing trend. If the p-value computed is greater than the significance level, α=0.05, the implication is that the trend is insignificant or no trend at all. At the Kpetoe area of the watershed, the rainfall shows a decreasing trend for the following months: March, May, July, August and November while the remaining months had increasing trends. The trend in each category is insignificant (p>0.05). Also, the largest S values obtained at Kpetoe corresponded to the most significant trend at the station. The rainfall is decreasing in July and September in the Tordzinu area of the watershed under study, however, the trend is insignificant (p>0.05) while the rest of the months had an increasing trend. The magnitude of the increase or decrease is indicated as Sen's slope in mm/year. It is worth noting that the increasing trend in January, February and November of the aforementioned part of the Tordzie watershed is significant (p<0.05). The result of Sen's test of precipitation time series is shown in Table 7 at a 95% confidence level. The largest increasing slope of significant annual precipitation occurred in Tordzinu in November with an increase of 1.685 mm/y. This is plausible evidence of climate variability.

Table 6: Descriptive statistics of monthly rainfall for Kpetoe and Tordzinu.

	Kpetoe						**Tordzinu**					
Months	**mean**	**standev**	**cv**	**skewness**	**min**	**max**	**mean**	**standev**	**cv**	**skewness**	**min**	**max**
January	17.7	22.3	1.3	1.3	0.0	78.4	11.0	16.1	1.5	1.3	0.0	54.3
February	49.1	42.1	0.9	2.4	1.3	212.7	23.2	27.6	1.2	2.7	0.0	139.3
March	107.1	58.5	0.5	0.8	23.1	265.7	73.5	50.6	0.7	0.7	0.0	177.4
April	141.7	56.0	0.4	-.0.3	4.9	255.6	88.7	57.3	0.6	1.0	0.0	261.3
May	155.1	62.6	0.4	0.6	35.5	325.4	158.0	95.0	0.6	1.9	0.0	522.2
June	185.5	77.6	0.4	0.9	74.4	374.4	139.9	70.5	0.5	0.6	0.0	320.9
July	126.9	61.9	0.5	0.5	30.2	283.6	54.4	47.8	0.9	1.2	0.0	188.3
August	91.3	67.9	0.7	0.7	8.0	254.1	31.3	32.3	1.0	1.3	0.0	107.6
September	177.9	85.7	0.5	1.4	55.8	454.2	94.4	61.6	0.7	1.1	10.0	273.7
October	151.3	43.2	0.3	0.3	77.4	248.6	113.6	55.9	0.5	0.4	0.0	229.8
November	49.7	32.3	0.6	1.3	5.8	133.8	67.1	47.1	0.7	0.5	0.0	158.4
December	31.6	32.7	1.0	0.8	0.0	103.4	27.4	36.0	1.3	1.8	0.0	137.1

Table 7: Mann-Kendall Trend Test for monthly rainfall at Kpetoe and Tordzinu

	Kpetoe					**Tordzinu**				
Months	K's t	P-value	S	Var(s)	Sen's slope (mm/month)	K's t	P-value	S	Var(s)	Sen's slope (mm/month)
Jan	0.123	0.176	55.000	3369.667	0.050	**0.277***	0.022	109.000	2873.000	**0.167**
Feb	0.166	0.098	77.000	3459.667	0.823	**0.227***	0.043	97.000	3112.333	**0.650**
Mar	-0.067	0.705	-31.000	0.000	-0.500	0.002	0.500	1.000	3139.667	0.000
Apr	0.148	0.125	69.000	0.000	1.257	0.189	0.074	82.000	3140.667	1.654
May	-0.032	0.606	-15.000	0.000	-0.464	0.092	0.243	40.000	3140.667	1.391
Jun	0.140	0.140	65.000	0.000	1.500	0.074	0.290	32.000	3140.667	1.116
Jul	-0.282	0.988	-131.00	0.000	-2.808	-0.014	0.536	-6.000	3140.667	-0.157
Aug	-0.144	0.875	-67.000	0.000	-1.653	0.030	0.415	13.000	3139.667	0.073
Sep	0.209	0.052	97.000	0.000	2.373	-0.048	0.639	-21.000	3139.667	-0.420

Oct	0.114	0.190	53.000	0.000	0.717	0.177	0.089	77.000	0.000	1.620
Nov	-0.084	0.750	-39.000	0.000	-0.314	**0.223***	0.044	97.000	0.000	**1.685**
Dec	0.078	0.276	36.000	3452.000	0.153	0.042	0.380	18.000	3123.000	0.047

Significant trend at 0.05 alpha

The declining rainfall observed and its associated variability in time and space could be attributed to climate change. The general variability in the rainfall pattern and the trend as observed in Table 7 in the months agreed with the result of Dumenu and Obeng (2016). He suggested that the declining rainfall total and increased variability is due to climate change. Mahmood and Jia (2017) in a related study reported a similar trend in the rainfall pattern and they attributed the trend could be linked to the local effects such as the land use/land cover changes, urbanisation, regionalisation and globalisation. Also, Ntajal *et al.* (2016) researched the same ecological zone in nearby Togo in a Mono river basin and obtained similar rainfall characteristics.

Rainfall variability and its Implication for Agriculture

The implication for the decreasing trend of rainfall is that short duration crops should be considered and also varieties with drought resilience should be developed. Additionally, as the amount of rainfall is on the decline coupled with its erratic nature, it is leading to rain-fed crop production challenges. If this trend continues, it will result in food insecurity challenges. Another adaptation strategy to adopt is to adjust the planting date to fit in with the onset of the rainfall to maximise its utilisation besides irrigation measures to minimise crop failure as a result of inadequate rainfall. On the other hand, the increasing trend has both negative and positive outlooks for agriculture. The negative aspect is the flood risk and the inundation of the agricultural fields and its associated challenges to agriculture production.

However, the flood as a result of the increasing trend of rainfall can be harvested and stored for dry season farming thereby leading to all-year-round production and consequently increase food production and food security enhanced. Rainfall variability will likewise affect agriculture economically. The impacts could be a reduction in farm gains, costs, resources, demand and local comparative advantages of trade. Again, the extent of rainfall variation and its terrestrial distribution may cause changes that may affect the capacity to increase the acreage of agriculture production. Besides, fluctuations in rainfall as a result of climate variation may stress the soil moisture content, essential for sprouting and crop stand establishment in the rain-fed areas.

The rainfall variability also have implications for livestock production. Reduction of rainfall amount and distribution resulting in drought conditions can lead to limited or insufficient forage and pasture for livestock production. This could result in weight losses of the livestock due to insufficient feeding. Again, during the period of heavy rainfall, livestock could be more predisposed to diseases and sicknesses since certain diseases thrives in the wet weather conditions such as pneumonia. Frequent deaths could also be occasioned due to the cold weather, especially in Ghana where most livestock are reared on the free range or semi-intensive system. This system of keeping livestock in Ghana mostly leads to feeding challenges during the rainy season since there is no supplementary feeding arrangement.

CONCLUSION AND RECOMMENDATION

The study revealed an increasing rainfall amount in the minor season. The magnitude of rainfall at the Kpetoe side of the watershed is more than the Tordzinu area. The largest increasing slope of significant precipitation occurred in Tordzinu in November with an increase of 1.685 mm/y. Dependable rainfall information provided is of vital importance to rain-fed farmers. Also, with the general increase in the occurrence of precipitation events in some months over the past years, and some months recorded extreme precipitation, the vulnerability for flood risks may be aggravated in the future and consequently result in challenges in the water storage structures and damage to bridges in the course of the basin. It is recommended that rain-fed agriculture practitioners adjust the cropping to fit in the onset of rainfall to optimise rainfall utilisation and also practise smart agriculture including irrigation among others.

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Competing Interest:
The authors declare no competing interest.

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