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Assessment of the Trends, Changes and Variations in Rainfall and its Economic Impact on North-East Region of Ghana for the 1990-2019 Period

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Establishing Trends, Changes and Variation in Rainfall and its Economic Impact on North-East Region of Ghana for the 1990-2019 Period

Abstract
The study assessed variation and trend changes of rainfall in the North-East Region of Ghana by examining decadal, annual, monthly and daily changes from 1990 to 2019. Annual, seasonal and monthly data were computed from the daily rainfall data and statistically and graphically analysed to determine variability and trend changes. The highest annual maximum rainfall (393.4 mm) was recorded in 1991 and the lowest minimum rainfall (0.2 mm) in 2005. The mean daily rainfall decreased from 2.94 mm in 1990-1999 to 2.88 mm (2.04%) in 2000-2009 then to 2.73 mm (7.14%) in 2010-2019. The wettest month in the region was September with a mean of 192.3 mm and the driest is January with a mean of 3.3 mm. The seasonal mean daily rainfall for the dry season changed from 0.73mm in 1990-1999 to 0.83mm, (13.7%) in 2000-2009 then to 0.89mm (21.9%) in 2010-2019. The rainy season rainfall changed from 5.1 mm in 1990-1999 to 4.9 mm in 2000-2009 (3.9%) and to 4.6 mm (9.8%) in 2010-2019. The total dry season rainfall, however, increased from 1320.7 mm to 1495.2 mm (13.2%) between 1990-1999 and 2000-2009 and to 1579.7 (19.6%) in 2010-2019. All three decades show significant wetting trends with the 2010-2019 decade showing the highest rate of wetting. Generally, there was significant wetting trend (slope is positive) in the dry season and a significant decreased in wetting trend (slope is negative) in the wet season.
***Keywords*: Trend, Variability, Rainfall and Seasonality**

INTRODUCTION

Climate is the set of atmospheric variables existing in a given place over a long period of time [7]. Among the variables that constitute climate are precipitation, atmospheric humidity, temperature, atmospheric pressure, insolation and wind. Increasing variation in climate and its impact have become more threatening to human existence globally. Climate change is of critical importance globally. Climate change is currently adversely impacting the health and lives of people around the world particularly in low-income countries where there are challenges of rural-urban drift and unfriendly human activities such as grazing and pollution [7][9]. The severity of climate change particularly in Africa is more than that of terrorism [3]. Rainfall and temperature are the most important fundamental physical parameters that influence human well-being [5][9]. Rainfall is one of the parameters that determine spatial and temporal distribution of runoff, soil moisture and groundwater reserves socioeconomic activities, agricultural productivity particularly in sub-Saharan Africa where over sixty percent of the population are employed through rain fed agriculture amongst others [1][2]. The activities of man and natural occurrences result in global warming, which causes variations in the earth rainfall worldwide [3]. Human induced changes such as bush burning, deforestation and urbanisation increase the risk of vulnerability to climate change.

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The pattern and the amount of rainfall are among the most vital factors that affect agricultural production, industrial, domestic water supply, hydroelectric power generation and other cultural practices [4][8]. These changes have significant adverse effects on natural and human resources and the economy in general. Knowledge base for better management of the environment in the selected area

Objectives

To establish trends, changes and variation in rainfall and their economic impact on North-East Region for the 1990-2019 Period

Research Questions

The key research question is:

- What are the trends, changes and variation in rainfall and their economic impact on North-East Region for the 1990-2019 Period

Physical Characteristics of the Study Area

North-East Region is one of the sixteen regions of Ghana. It is located in the north of the country and was created in December 2018 after a referendum was voted upon to break it off of the Northern region. The region's capital is Nalerigu. The Region is bordered on the north by the Upper East region, on the east by the eastern Ghana-Togo international border, on the south by the Northern region, and on the west by the Upper West region. North-East region is made up of 6 districts. The region covers an area size of 9,072 km^2.

The Region is characterized by a gently rolling topography with the Gambaga escarpment, which marks the northern limits of the Voltaian sandstone basin. The scarp stretches from East-West and peak at Nakpanduri, with waterfalls presenting its beauty. Important drainage features in the region include the White Volta, which enters the region in the northeast and is joined by the Red Volta near Gambaga escarpment with the Nawonga and Moba rivers also draining the South-Western part.

METHODOLOGY

Data Collection

Secondary data from the Tamale Meteorological Agency, Tamale Airport office was used to study the trend and variability of rainfall between 1990 and 2019.

RESULTS AND DICUSSIONS

Rainfall Characteristics

About 86. % (Fig. 2) of the annual rainfall was recorded during the wet season (May-October) with the peak period (July-September) alone contributing (52.4%). The wet season contributed a mean rainfall of 897.68 mm (86.%) per annum while the dry season contributed 146.5 mm (14.%) per annum. The mean seasonal rainfall was 897.68 mm in the wet season and 146.52 mm in the dry season; 72.% greater than the dry season. The amount of rainfall varies widely throughout the period (Fig.1). Rainfall ranges from a monthly minimum of 0.2 mm to a maximum of 393.4 mm and a mean of 87.02 mm.

Trend and Changes in Inter-Annual Rainfall Data Series

Figure 1 shows that in 14 out of the 30 years the annual rainfalls were below the period mean.

The highest annual rainfall occurred in the year 1991 where 1459.6 mm (4.7%) rainfall was recorded and the lowest was in 2017 with 694.4 mm rainfall representing 2.2%.The mean annual rainfall decreased by 1.8% in 2000-2009 and 5.3% in 2010-2019. The maximum monthly rainfall of 393.4 mm occurred in August, 1991 during the period. The period annual mean rainfall was 1044.2 mm. Rainfall in the 1990-1999 decade were averagely the highest. Generally, there was significant decreased in wetting trend (slope is negative and significantly lesser than zero) over the period at the rate of -2.93 mm per annum (R^2 = 0.021). Fig. 1 also shows a non-cyclical annual variation throughout the period. Ten very dry years and two very wet years were observed during the 30 years.

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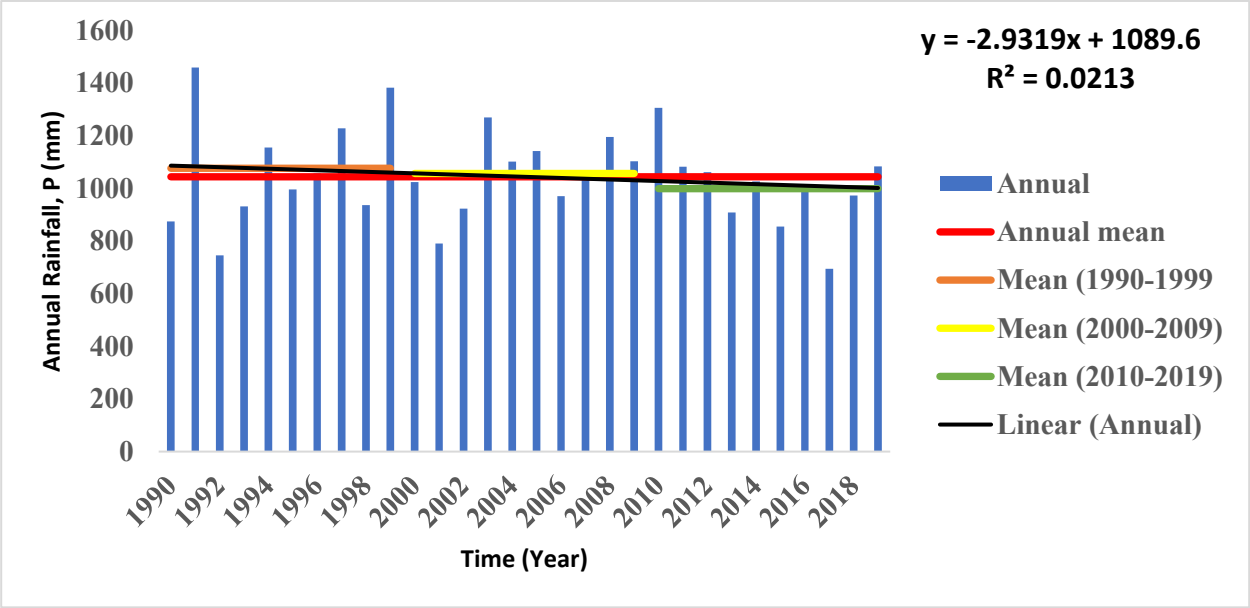

Figure 1: Variation in Inter-Annual Rainfall Over three Decades

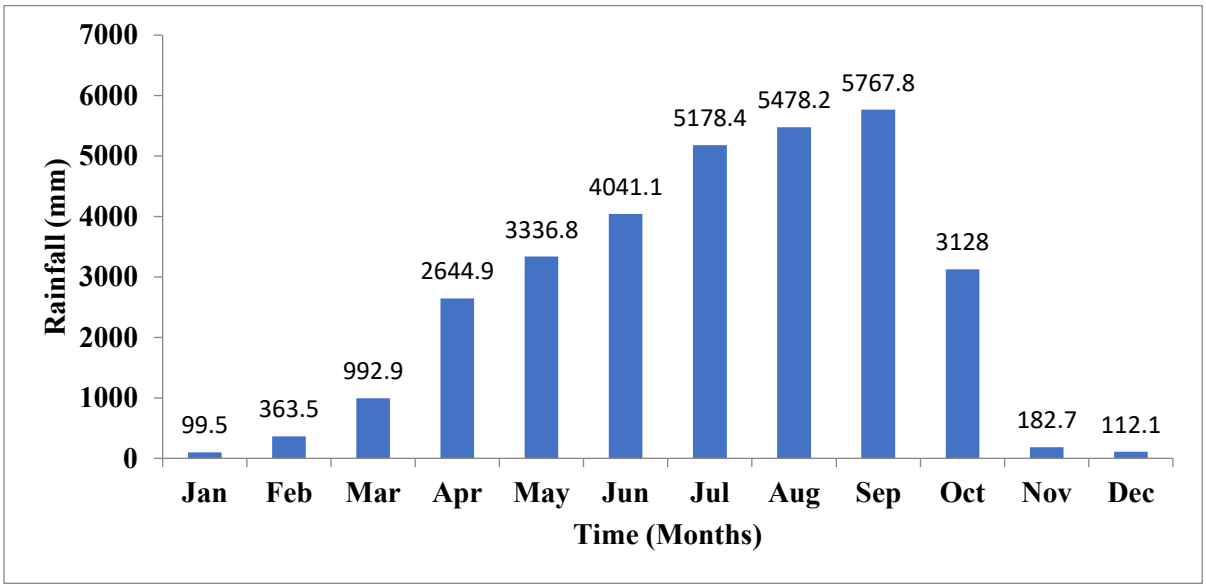

Figure 2: Intra-Annual rainfall variations in the North-East Region of Ghana (1990-2019)

Changes in Annual Maximum Rainfall

Fig. 3 shows the variations in annual maximum and decadal mean maximum rainfalls. The highest annual maximum rainfall (393.4 mm) was recorded in 1991 and the lowest minimum rainfall (0.2 mm) in 2005. The mean decadal maximum rainfall for 1990-1999 and 2000-2009 were 283.37 mm and 266.42 mm higher than the period mean decadal maximum value of 265.16 mm. However, the 2010-2019 decade mean maximum rainfall was 245.68 mm lower than the period mean maximum value.

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Intra-Annual Variations and Changes in Mean Daily and decadal Rainfall

The decadal variation in mean daily rainfall is presented in Fig 4. All the three decades show high variation in the rainy season (May-October). The mean daily rainfall decreased from 2.94 mm in 1990-1999 to 2.88 mm (2.04%) in 2000-2009 then to 2.73 mm (7.14%) in 2010-2019. The wettest month in the region was September with a mean of 192.3 mm and the driest is January with a mean of 3.3 mm. Fig. 2 shows a large intra-annual variability in the monthly mean rainfall with a general increasing trend. The mean monthly rainfall shows very high and low coefficients of variations ranging from 29% (September) to 134.7% (January), indicating the existence of moderate and high changes in monthly rainfall.

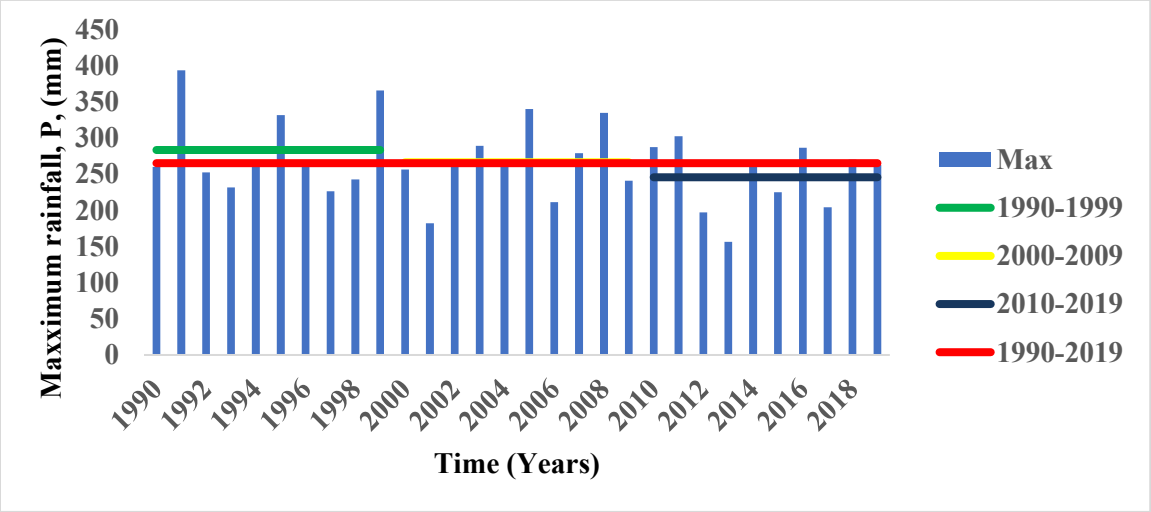

Figure 3: Annual Maximum Rainfall in North-East Region of Ghana

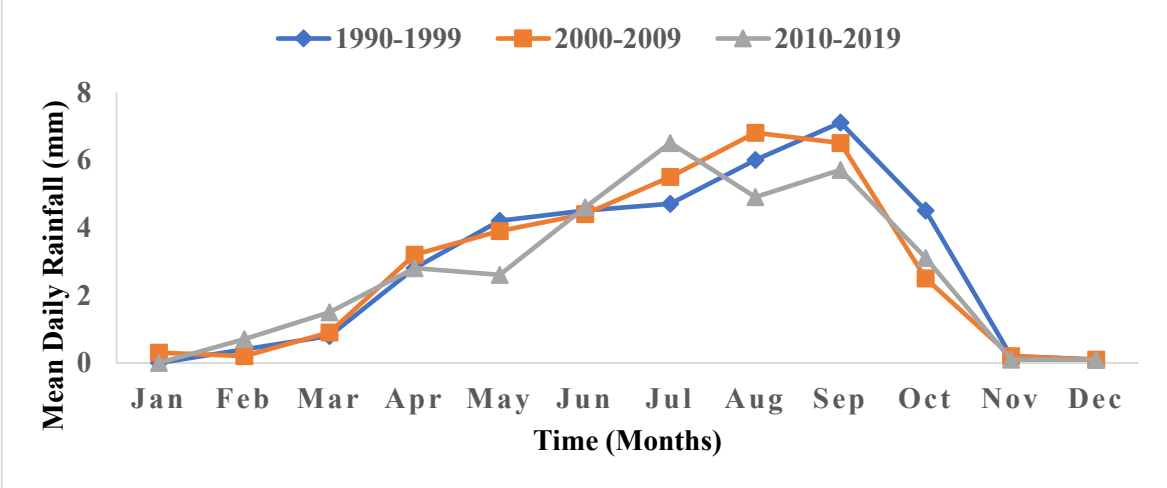

Figure 4: Inter-Annual Rainfall Variations in North-East Region of Ghana

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Seasonal Changes in the Regional Rainfall

The seasonal mean daily rainfall for the dry season changed from 0.73mm in 1990-1999 to 0.83mm, (13.7%) in 2000-2009 then to 0.89mm (21.9%) in 2010-2019. The rainy season rainfall changed from 5.1 mm in 1990-1999 to 4.9 mm in 2000-2009 (3.9%) and to 4.6 mm (9.8%) in 2010-2019. The total dry season rainfall, however, increased from 1320.7 mm to 1495.2 mm (13.2%) between 1990-1999 and 2000-2009 and to 1579.7 (19.6%) in 2010-2019 (Fig. 6). All three decades show significant wetting trends with the 2010-2019 decade showing the highest rate of wetting. The rainy season rainfall magnitudes for the period oscillated between 619.4 mm (2014) and 1287mm (1991). The wettest rainy season occurred in 1991 and the driest in 2017. The mean decadal rainy season rainfall in 2010-2019 decreased by 6.3% below the period mean, 1990-1999 and 2000-2009 increased 5.2% and 1.1%, respectively above the period mean (Fig. 6). The annual dry season rainfall magnitudes oscillated between 39.5 mm (1995) and 288.5 mm (1997) (Fig.6). The 2000-2009 and 2010-2019 decades recorded means of 24.9 mm (2.0%) and 26.3 mm (7.90%), respectively above the period mean (24.4 mm) while the 1990-1999 recorded 22 mm (9.8%) below the period mean. Generally, there was significant wetting trend (slope is positive and significantly greater than zero) over the period at the rate of 0.17 mm per annum ($R^2 = 0.02$) in the dry season and a significant decreased in wetting trend (slope is negative and significantly lesser than zero) over the period at the rate of -0.65 mm per annum ($R^2 = 0.05$) in the wet season. .

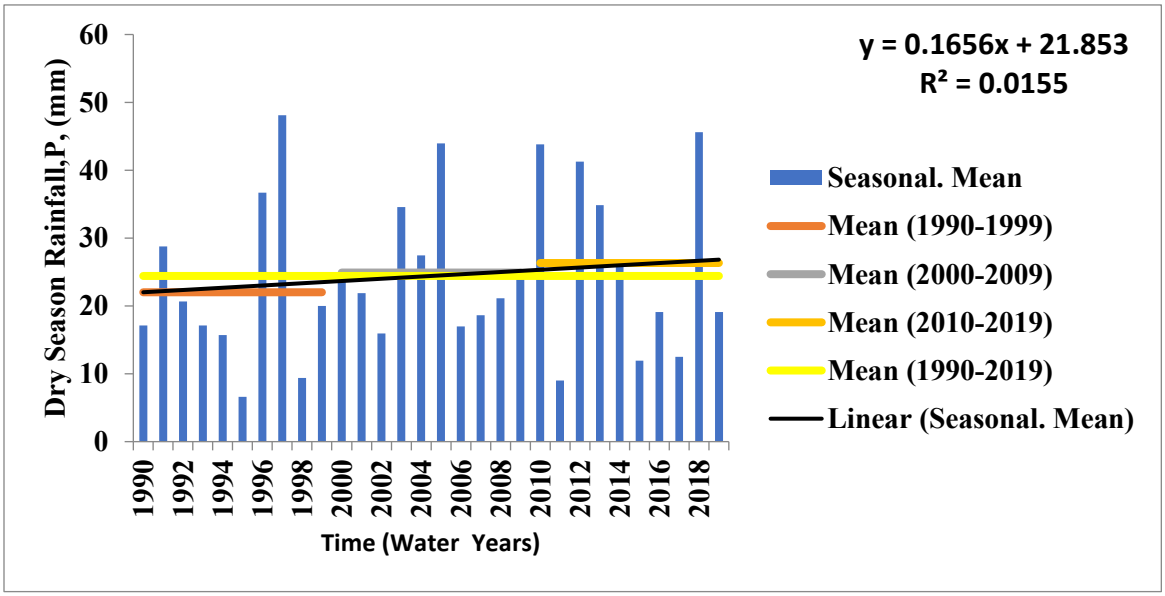

Figure 5: Dry Season and Decadal Variations in Rainfall (1990-2019)

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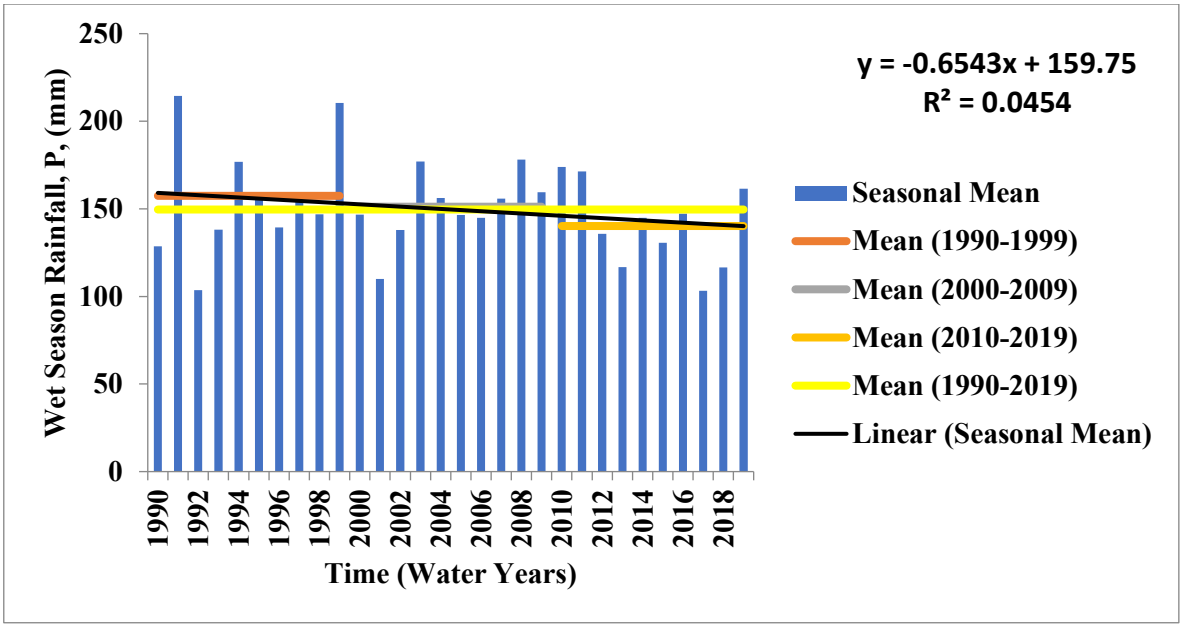

Figure 6: Wet season rainfall Trend in the 1990-2019

Changes in Rainfall Days

There was a maximum of 100 days (in 2008) and a minimum of 49 days of rainfall (in 1992) during the period. The highest (1459.6 mm) and the lowest (694.4 mm) annual rainfall occurred in 1991 and 2017 respectively. The highest annual rainfall magnitude (Fig. 1) and rainfall days (Fig. 8) did not occurr in the same year. Thus the 1991 rainfalls were of higher intensities and/or longer durations. The mean number of rain days as presented on Figure 8. The mean decadal rainfall days increased in the 2000-2009 decade by 7.81% from 1990-1999 and has decreased by 4.87% in 2010-2019 from 2000-2009.

There is a high annualy variation in rainfall days (Fig. 8) for the period 1990-1999. The minimum mean rainfall days for the period (7 days) occurred in December and the maximum (456 days) in September. The number of days increases from January to September and drops from September to December. Intra-annually, the highest period rainfall (456 mm) occurs in September and the lowest (7 mm) in December. The highest rainfall days (465 days) for the period occurred in September and the lowest in December. These, partly, explain why September and October were considered for determining borehole yield during the rainy season.

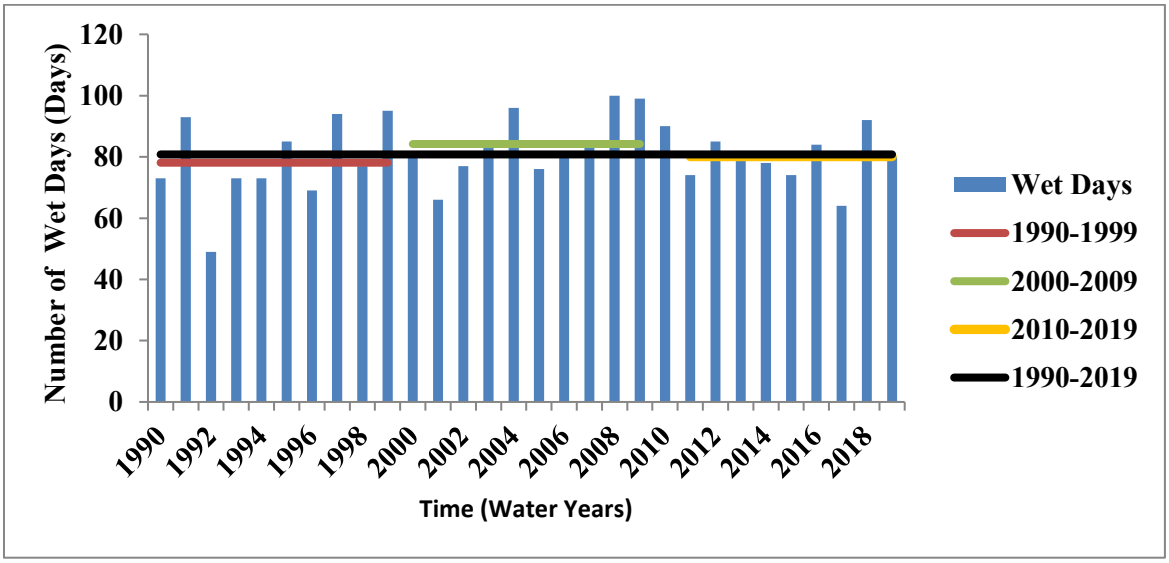

Figure 7: Inter-Annual Variation in Number of Rainfall Days

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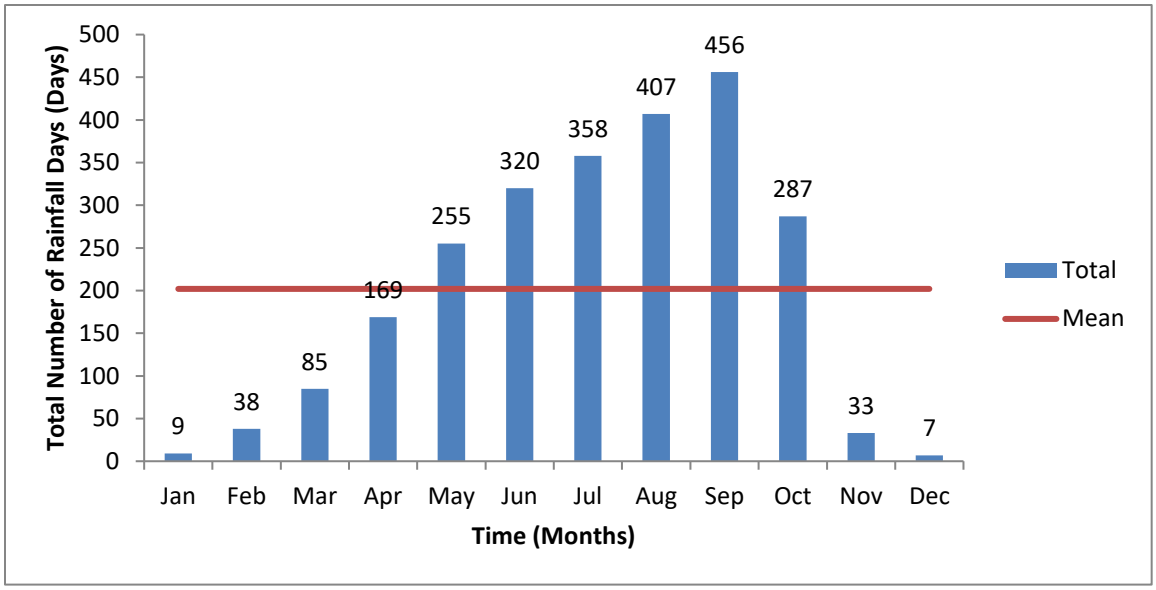

Figure 8: Monthly Variation in Number of Rainfall Days

Changes in Mean Annual Daily Rainfall

The maximum annual daily rainfall (4.0 mm) for the period was attained in 1991 and the minimum (1.9 mm) in 2017. The mean decadal daily rainfall has high monthly variations in the 1990-1999 and 2010-2019 and averagely low in the 2000-20009 decade (Fig. 9). The mean decadal daily rainfall increased from the period mean of 2.8 mm to 2.9 mm (3.6%) in 1990-1999 and 2000-2009 but dropped in 2010-2019 to 2.7 mm (3.6%).

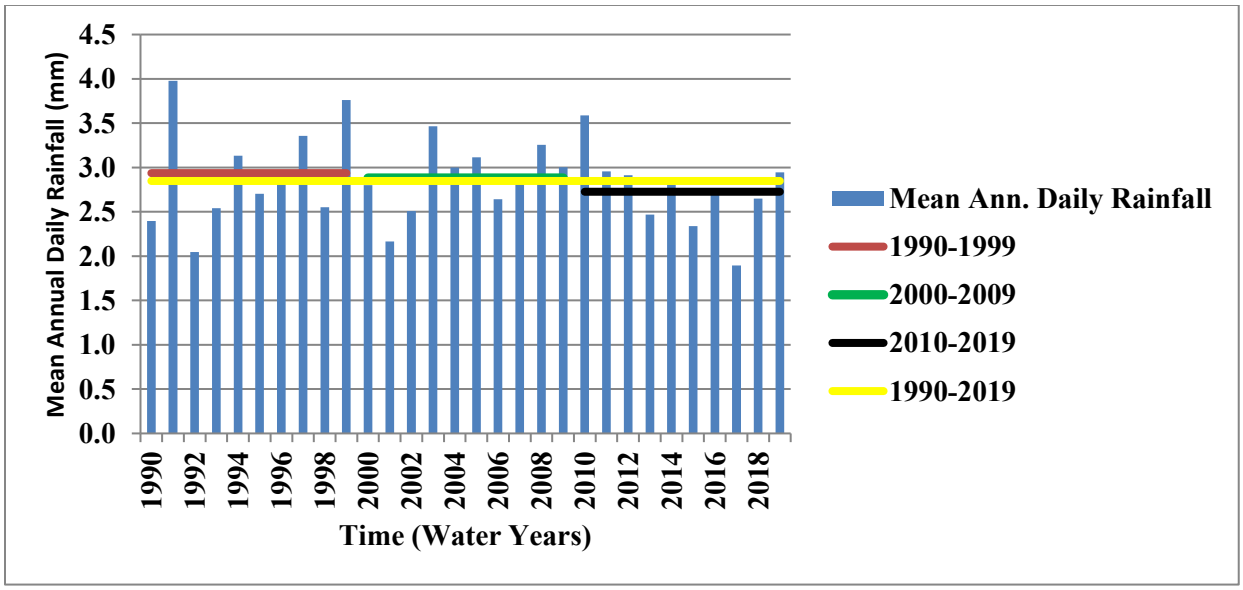

Figure 9: Inter-annual Variation in Mean Daily Rainfall (1990-2019)

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Mean Seasonal Variability in Rainfall

The objective here was to find out if the increase in the rainfall appears throughout the period or is concentrated during specific years (poor annual distribution) which can lead to low groundwater yield in those months in the region. The rainfall variation in the rainy season varied widely while the dry season recorded low variation over the period. The rainy season varied between 103.2 mm and 214.5 mm and the dry season between 6.6 mm and 48.1 mm. The standard deviations for the rainy and dry season are, respectively, 27.0 mm and 11.7 mm and the coefficient of variation are 18.1 and 48.0%. There were 5 wet years in 1990-1999, 4 wet years in 2000-2009 and 6 wet years in 2010-2019 decade. A wet year is the year whose rainfall is less than the period mean. However, the total seasonal rainfalls decreased by 1.8% (10766.2 to 10568.7 mm) in the 2000-2009 decade and 5.5% (10568.7 to 9991.0 mm) in the 2000-2009. The rainy season rains decreased from 9445.5 to 9073.5 (3.9%) in 2000-2009 and from 9073.5 to 8411.3 (7.3%) in 2010-2019 and the dry season rains increased from 1320.7 to 1495.2 (13.2%) in 2000-2009 and from 1495.2 to 1579.7 (5.7%) in 2010-2019.

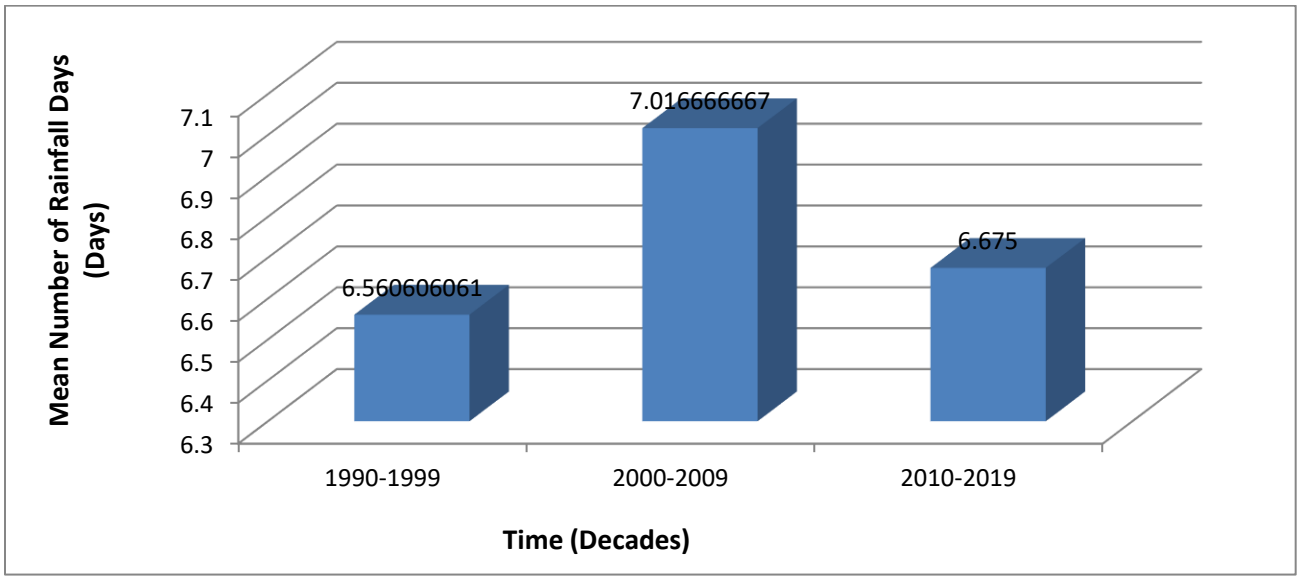

Figure 10: Decade and Period Mean Number of Rainfall Days

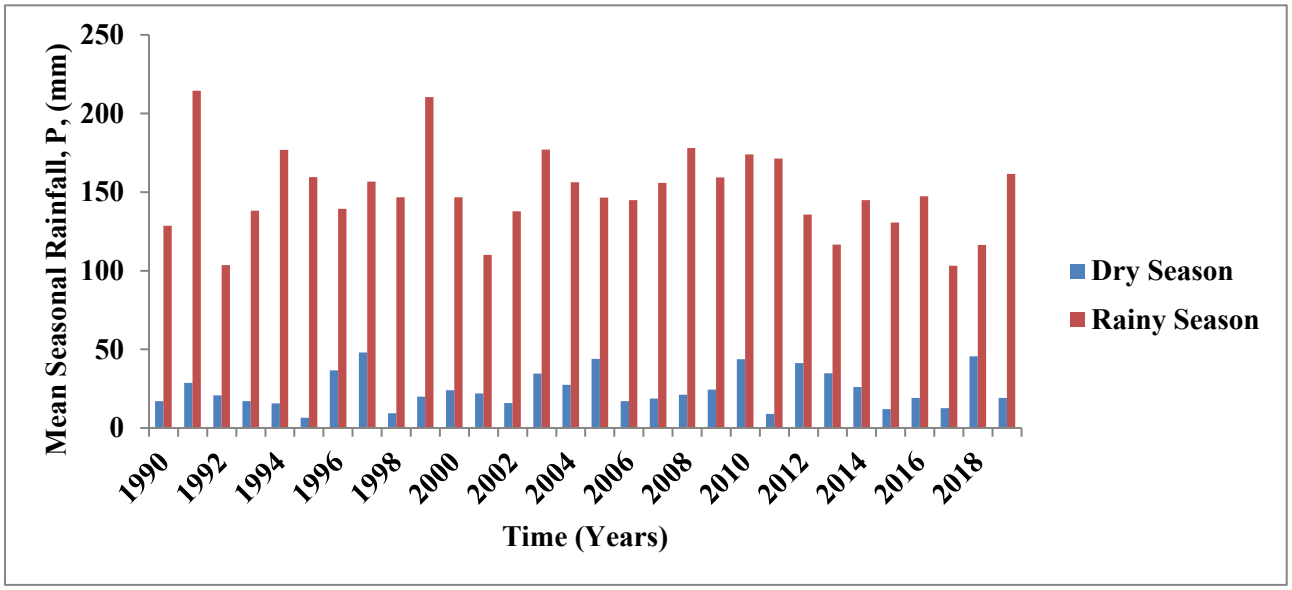

Figure 11: Variability in Seasonal Rainfall (1990-2019)

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Table 1: Basic Statistics of Seasonal Rainfall Variability (1990-2019)

Season	Minimum	Maximum	Mean	Stdev	CV (%)
Dry	6.58	48.08	24.4200	11.70617	48.0
Rainy	103.23	214.50	149.6128	27.04076	18.1

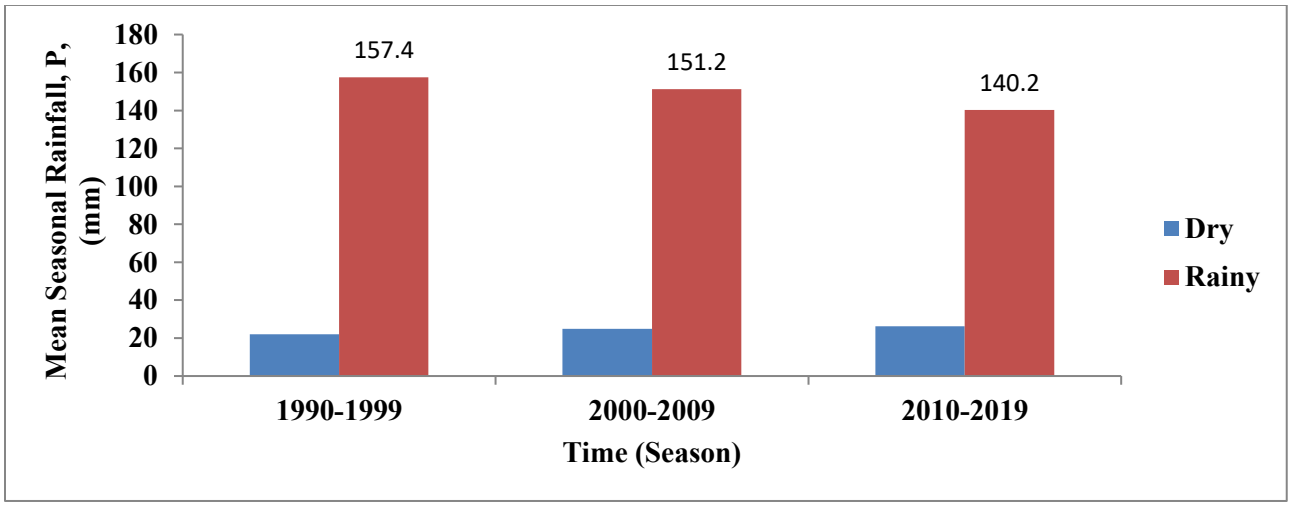

Figure 12: Decadal Changes in Seasonal Rainfall (1990-2019)

Impact of Rainfall on Economic Activities

Changes and variations in climate is a threat to agriculture and food security in North-East Region of Ghana because of the loss in food production through crop failure and increase in disease and mortality rate of livestock. One of the main elements of climate change for agriculture is the variability in rainfall that directly impact soil moisture. The high degree of rainfall variability between 1990 and 2019 in North-East Region, especially the rural communities, will restricts crop management strategies and overall crop water productivity. The persistent in general reduction in the number of wet months and increase in the number of dry months have raised concern among the Regional development planners regarding how to cope with losses due to seedling mortality and crop failure, instances of food insecurity, and increasing scarcity of water resources in the region. The major challenge is at the seedlings establishment phase as a result of prolonged dry seasons (short wet season). Changes in patterns, trends, frequencies and intensities of rainfall would exacerbate variation in runoff, infiltration, soil moisture contents and groundwater recharge. Short wet season reduces groundwater recharge which in effect reduces groundwater yield and these affect economic activities like food production, shear nut processing, rice processing and pito brewing.

CONCLUSION

This study examined variability, trend and changes of rainfall in North-East Region of Ghana. Rainfall in the study area is characterised with increasing trend and high concentration in the months of August and September, which increases the risk of flooding. The highest annual maximum rainfall (393.4 mm) was recorded in 1991 and the lowest minimum rainfall (0.2 mm) in 2005. The wettest month in the region was September with a mean of 192.3 mm and the driest is January with a mean of 3.3 mm. Generally, there was significant wetting trend (slope is positive) in the dry season and a significant decreased in wetting trend (slope is negative) in the wet season. The trends in dry season rainfall also showed inter annual rising trend and minimal variability, and this further confirms the manifestation of global warming in the region. The variations in rainfall will have major implications on agriculture, socioeconomic activities and the environment, and hence the need to adopt strategies to minimised the problems of climate change.

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RECOMMENDATION

Findings from the research can be successfully used to manage North-East Region of Ghana. Government and Non-government agencies can formulate plans and policies that will accommodate changes in rainfall and patterns.

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