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Analysis of Rainfall Variability in Ghana

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Abstract: Understanding the decadal and/or annual variability and distributions of rainfall of a region is important and useful especially for agricultural activities. Rainfall data from 77 stations were analysed to determine the mean annual and inter-decadal rainfall variability and distribution in Ghana for the period 1981-2010. The ArcView GISTM (version 3.2) software was the tool used to analyse the temporal variability of the decadal mean rainfall for the periods 1981-1990, 1991-2000 and 2001-2010. The study shows variation on high and low rainfall distributions in the country. With respect to previous studies, results showed a general decline in mean annual rainfall for the period 1981-2010 with high rainfalls shifting to the South-western corner of the country. However, it could be deduced that mean decadal rainfall amounts in Ghana is on a gradual increase from 1981 to 2010, though the rate at which it is increasing is on a decline, i.e. from 8.6 % in 1991-2000 to 2.6 % in 2001-2010. We recommend that the agro-meteorological sub-department of the GMET studies the inter-annual and/or inter-decadal rainfall variability and distribution in the country and appropriately inform farmers of the same in order to avoid total crop failure. We also recommend that studies on rainfall variability in Ghana be carried out in a continuous manner as and when new rainfall data is available.

Keywords: Rainfall variability, rainfall distribution, mean rainfall, Ghana

INTRODUCTION

Water makes up 70% of the earth. It is an important component in everyday life, from basic domestic use to national and global development [1]. The use of rain water over the years has gained its importance as a valuable alternative or supplementary water resource. Rain water can be used for multiple purposes ranging from domestic and industrial water supply, sanitation and disease prevention and rainfed agriculture. It is thus evident that water forms an integral part of the development of human societies. The most critical factor that sustains crop productivity in rainfed agriculture is the availability of water. In Ghana, agricultural production serves as the main economic sector, employing about 56 % of the work-force and accounting for about 28 % of GDP [2]. However this sector depends heavily on rainfall. Variability of rainfall from season to season greatly affects soil water availability to crops, and thus risks crop productivity.

Most studies conducted in Ghana on rainfall variability and distributions were limited to selected regions or stations ([3], [4]). The results from these studies showed the risk of a dry spell during the rainy season to be higher in the south of the country than in the north. Reference [3] also observed similar trends in the intra-seasonal rainfall variability of Accra in the south and Tamale in the north. Reference [5] reported the variability and distribution of mean annual rainfall totals in Ghana as shown in Fig. 1, with mean rainfall values between 1,000-1,400 mm covering more than 50 % of the entire country. Higher mean annual rainfall amount exceeding 1,900 mm occurs in parts of Ashanti and Western Regions of Ghana.

Recent climate trends show highly variable inter-annual and inter-decadal rainfall amounts in Ghana. Various models predicted that rainfall will continue to decrease in all the agro-ecological zones and river basins of Ghana ([6], [7], [8], [9]) whilst other models also predicted increases in the mean annual rainfall averaged over the entire country [7]. This makes it very difficult to identify and/or predict with certainty the long term trends of rainfall in the country. Knowing the pattern of rainfall in a region is thus indispensable due to its usefulness in guiding water users, especially food producers in their planning and decision making.

This study, therefore, sought to analyze the variability of mean annual rainfall in Ghana to support decision-making, planning and designing in the fields of hydrology and agriculture. The output from this study will be compared to the result of [5] to properly discuss the spatial and temporal distribution of rainfall from pre-1980 and the last three decades (1981-2010). This is important especially to the agricultural sector since agricultural productivity in Ghana is heavily dependent on rainfall.

A. Objectives of the Study

The specific objectives of the study are to:

- Analyze the variability and distribution of mean annual rainfall in Ghana for 3 decades (1981-1990, 1991-2000 and 2001-2010);
- Compare changes in mean annual rainfall amount and distribution in Ghana between the result of [5] referred to as pre-1980, and the period 1981-2010; and

- Assess trends in mean annual rainfall in Ghana from 1981 to 2010.

The goal of this study is to improve decision-making and planning in the water and agriculture sectors by contributing to current knowledge on rainfall variability and distribution across Ghana.

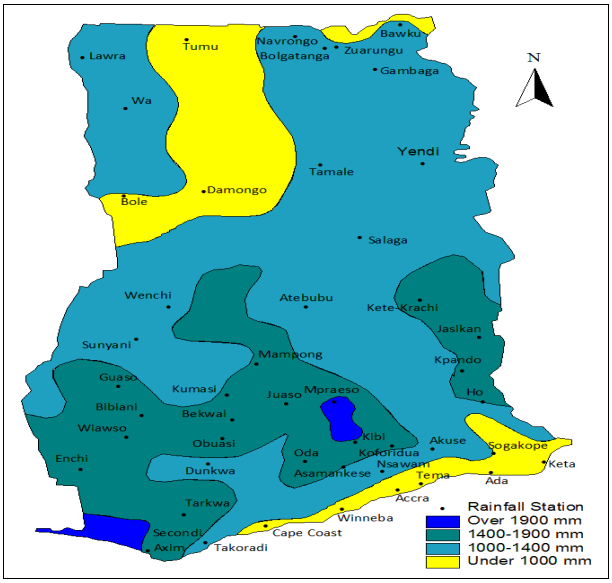


Fig. 1 Mean Annual rainfall distribution in Ghana (Source: Anang, 1977)

MATERIALS AND METHOD

A. *Study Area*

The study area is the whole of Ghana, which is located in the west coast of Africa. Ghana shares boundaries with Burkina Faso, Gulf of Guinea, Togo and La Cote d'Ivoire to the North, South, East and West, respectively. The country covers a total land area of 238,539 km² and lies between longitude 1.20° E and 3.25° W and latitude 4.50° N and 11.18° N. Administratively, the country is divided into ten (10) regions. These regions are shown in Fig. 2. Ghana has a total population of 24,223,431 with current growth rate of 1.9 % per annum. More than 50 % of the population lives in urban areas [10].

1) *Climate:* The climate of Ghana is tropical and humid. Except in the north where there is only one rainy season from April to September, two rainy seasons occur from April to July and from September to November. The seasonality in the rainfall patterns in Ghana is brought about by the movement of the Inter-Tropical Convergence Zone (ITCZ). Annual rainfall ranges from about 1,100 mm in the north to about 2,100 mm in the south-western part of the country. The annual mean relative humidity is about 44 % and 80 % in the north and south, respectively [11]. Temperatures in the country vary with seasons and elevation. In most areas, the highest and lowest temperatures occur in March and August, respectively. Mean temperatures is generally between 21 °C and 35 °C [12].

2) *Vegetation:* The north of the country is entirely within the Interior Savanna Ecological Zone. The vegetal cover in this area is open and is dominated by short grasses and neem trees. The middle section of the country, excluding the south-western part is dominated by dense tropical rainforest. The coastal section on the other hand is dominated by grassland interspersed with savannah [13].

3) *Geology and Soil:* The geology of northern Ghana is mainly underlain by the Birimian, Voltaian, and Granite Geologic Formations. On the other hand, the geology of the southern part of the country is dominated by Middle Precambian Rock and Birimian formation [14].

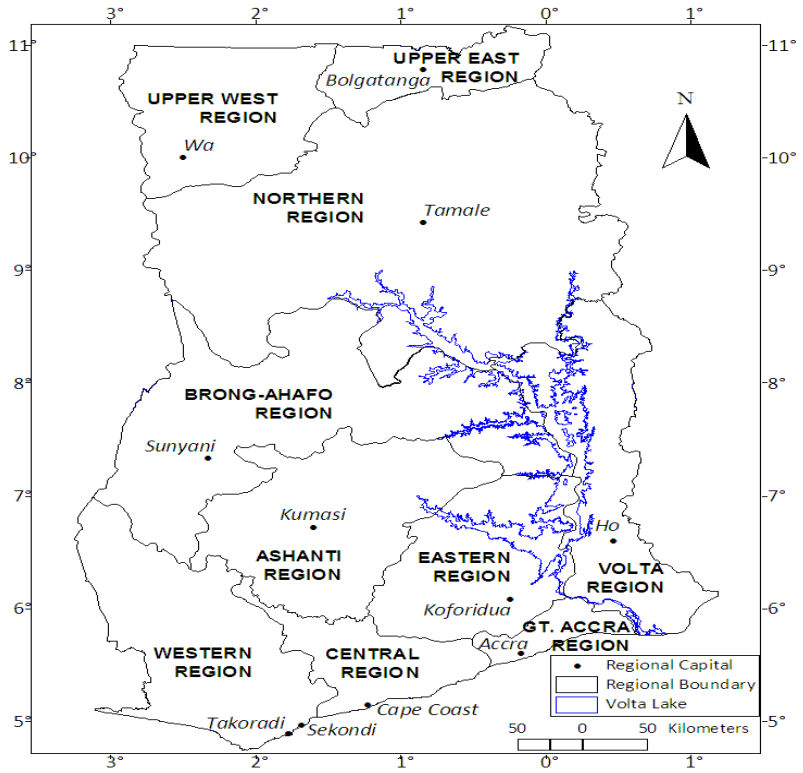


Fig. 2 Administrative regions of Ghana

Most of the soils of Ghana are developed on thoroughly weathered material, with Fluvisols and Leptosols common to all the ecological zones. The dominant soils type in the southern part of Ghana are the forest Oxysols, forest acid Gleysols and forest ochrosols. These soils types are porous, well drained and generally loamy, thus suitable for agriculture. Others include the savannah ochrosols and savannah lithosols along the coast of Ghana ([13], [14]).

4) *Topography:* The topography of the country is mainly undulating with most slopes less than 5 % and many not exceeding 1 % [15]. Ghana has few highlands rising to a height of 900 m and above. The highest mountain, Afadzato, is 1,500 m above sea level. Some steep escarpments in the middle portions and isolated places in the northern parts of the country are found. Generally, the land is relatively flat and the altitude in more than half of the country is below 220 m.

5) Drainage: Several rivers criss-cross the country with the Volta River basin dominating the country's river system. It includes the largest artificial lake in the world; Lake Volta, with a total surface area of 8,480 km². The Volta River is dammed at Akosombo and Akuse for two hydro-electric power generation plants. Other big rivers are the Pra, Birim, Ankobra and Tano. The Densu and Ayensu are among the smaller rivers in the country. The largest natural lake in the country is Lake Bosomtwi with a total area of 48 km². The coastal area of the country consists of plains and numerous lagoons near the estuaries of rivers. All the rivers empty into the Gulf of Guinea.

B. *Data Collection and Analysis*

1) *Rainfall data:* The data used for analysis in this study were daily rainfall data for 77 weather stations spread across the country. The data were acquired from the Ghana Meteorological Agency (GMet) and covered the period 1981–2010 (this was the period for which reliable data was available).

2) *Data analysis:* To assess the spatial and temporal distributions of rainfall in Ghana, annual precipitations from 1981 to 2010 were calculated for each station from the daily rainfall data. Mean annual precipitation were then calculated for the periods 1981-1990, 1991-2000, 2001-2010 and 1981-2010 in Microsoft Excel. The annual mean rainfall calculated for the periods 1981-1990, 1991-2000 and 2001-2010 were used to assess the inter-decadal variability of rainfall in Ghana. The mean annual rainfall for the period 1981-2010 was compared with the pre-(1981-2010) mean annual rainfall reported by [5] in order to establish changes in mean annual rainfall in recent times.

The ArcView GIS software (version 3.2) was used to plot the spatial distribution of mean decadal rainfall in Ghana. The mean annual rainfall for the decades were imported into ArcView as *dbf* files and analysed. With the help of the *Grid Analyst* extention, contour lines at 100 mm intervals were created for the mean annual rainfall amount using the *Output Grid Extention* option"same as the *Regional Boundary of Ghana"*. The Inverse Distance Weight (IDW) method was applied to

interpolate the mean annual rainfall values at regular intervals. The IDW method is based on the assumption that the interpolating point is most influenced by nearby points and less by the more distant points [16].

II. RESULTS AND DISCUSSION

A. *Mean Annual Rainfall in Ghana*

The distribution of the mean annual rainfall in Ghana for the period 1981-2010 is presented in Fig. 3. The mean maximum and minimum annual rainfall during the period 1981-2010 are 1,851.8 mm and 625.3 mm, respectively; with the mean annual value of 1,227.1 mm.

The mean annual rainfall amount between 1,400 and 1,900 mm is experienced in the South-western parts of the country, covering 3 administrative regions (Western Region and parts of Central and Brong-Ahafo Regions). The mean annual rainfall values below 1,000 mm is observed mainly in the extreme north of the country (Upper East and parts of the Northern and Upper West Regions) but also to a less extent in the south (part of Greater Accra Region).

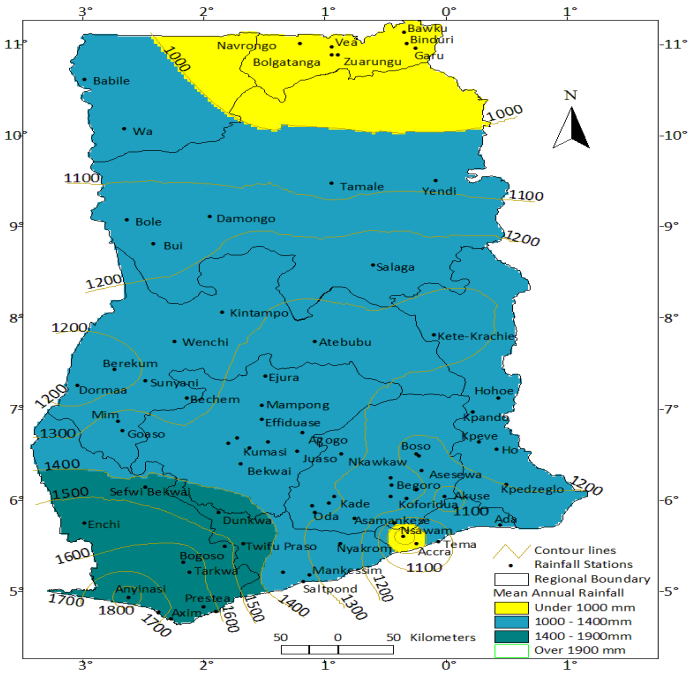


Fig. 3 Mean annual rainfall in Ghana for the period 1981-2010

The study of the inter-annual variability of the rainfall shows slight variation on high and low rainfall distributions in the country which according to [17] are influenced by sea surface temperature. The study shows a general decline in mean annual rainfall in the recent past 30 years (1981-2010). Mean annual rainfall totals below 1,000 mm has spread from the extreme northeast (Upper East Region) to the central north (Northern Region) and slightly to the extreme northwest (Upper West Region). Areas with mean annual rainfall below 1,000 mm in north-central to north-west have gained in rainfall amount and now lie in the range of 1,000 – 1,400 mm. In the south of the country, areas with rainfall below 1000 mm (along the coast) have shrank to a large extent, most of the areas now have annual rainfall in the range of 1,000-1,400 mm. Examination of the areas with mean annual rainfall between 1,400 mm and 1,900 mm showed that significant proportion received less rainfall (1,000 mm - 1,400 mm) between 1981 and 2010. Areas with rainfall between 1,400 and 1,900 mm are confined to the extreme south-western part of the country (Western Region). The mean annual rainfall values between 1,000 and 1,400 mm have dominated over 80 % of the entire country within the last three decades. This may be an indication of global warming, which is attributed to anthropogenic activities such as industrialization, deforestation, overgrazing, urbanization and farming close to rivers and water bodies.

Analysis of rainfall data at selected stations confirmed the general decline in the distribution of the mean annual rainfall in the entire country during the period 1981-2010. Apart from Accra which showed slight increase in the mean annual rainfall for the past three decades, the analysis at Navrongo (representing the northern belt of Ghana), Kumasi (middle belt) and Axim (southern belt) have shown decline in the mean annual rainfall for the period 1981-2010 (Fig. 4).

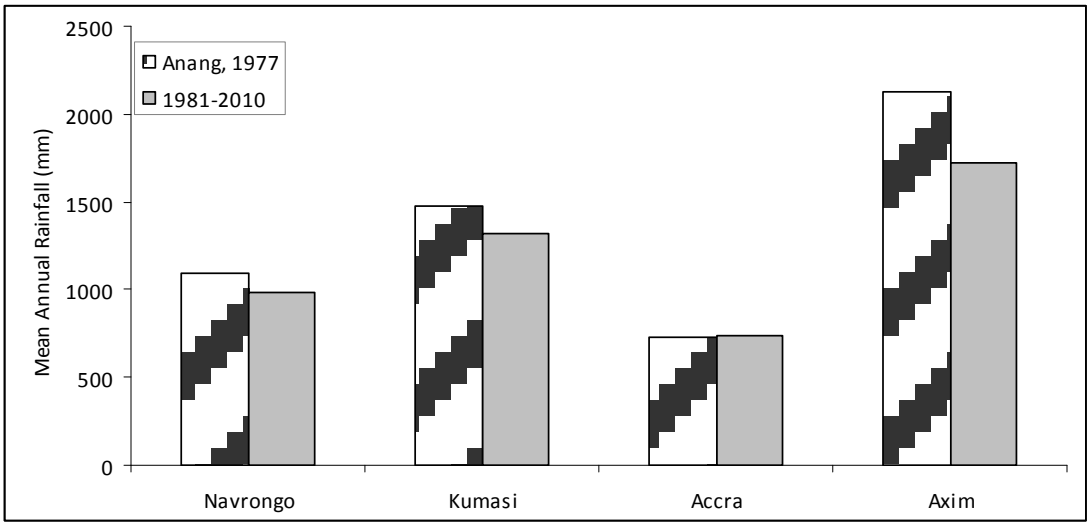
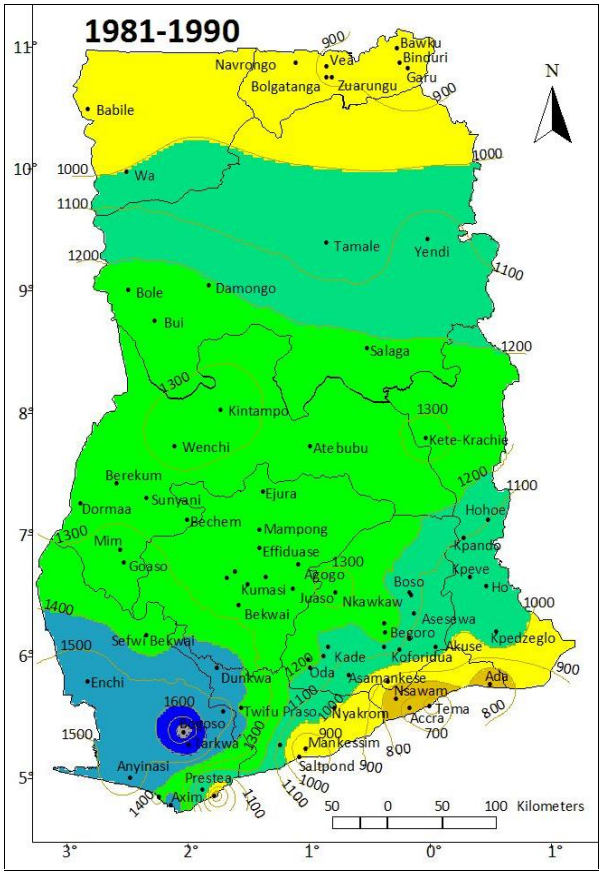
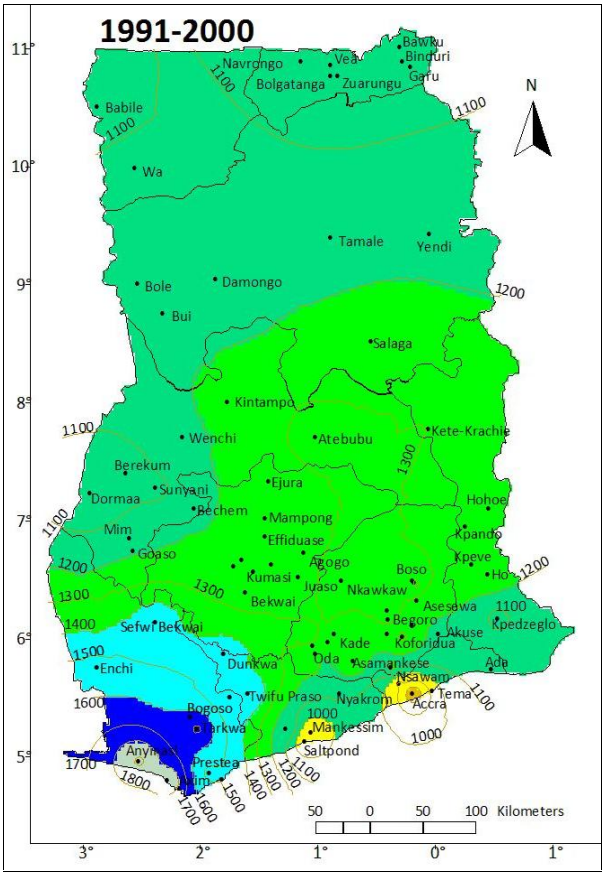


Fig. 4 Comparison of mean annual rainfall between Anang (1977) and the period 1981-2010 at Navrongo, Kumasi, Accra and Axim in Ghana

B. *Inter-decadal Distribution and Variability of Rainfall in Ghana*

Fig. 5 illustrates the inter-decadal distributions and variations of mean annual rainfall in Ghana for the periods 1981-1990, 1991-2000 and 2001-2010. Accra and Tema in the Greater Accra Region of Ghana consistently experienced low annual rainfall amounts, whilst high rainfall amount above 1,600 mm increases in spatial and temporal distributions in the South-Western corner of the country during the thirty years period.





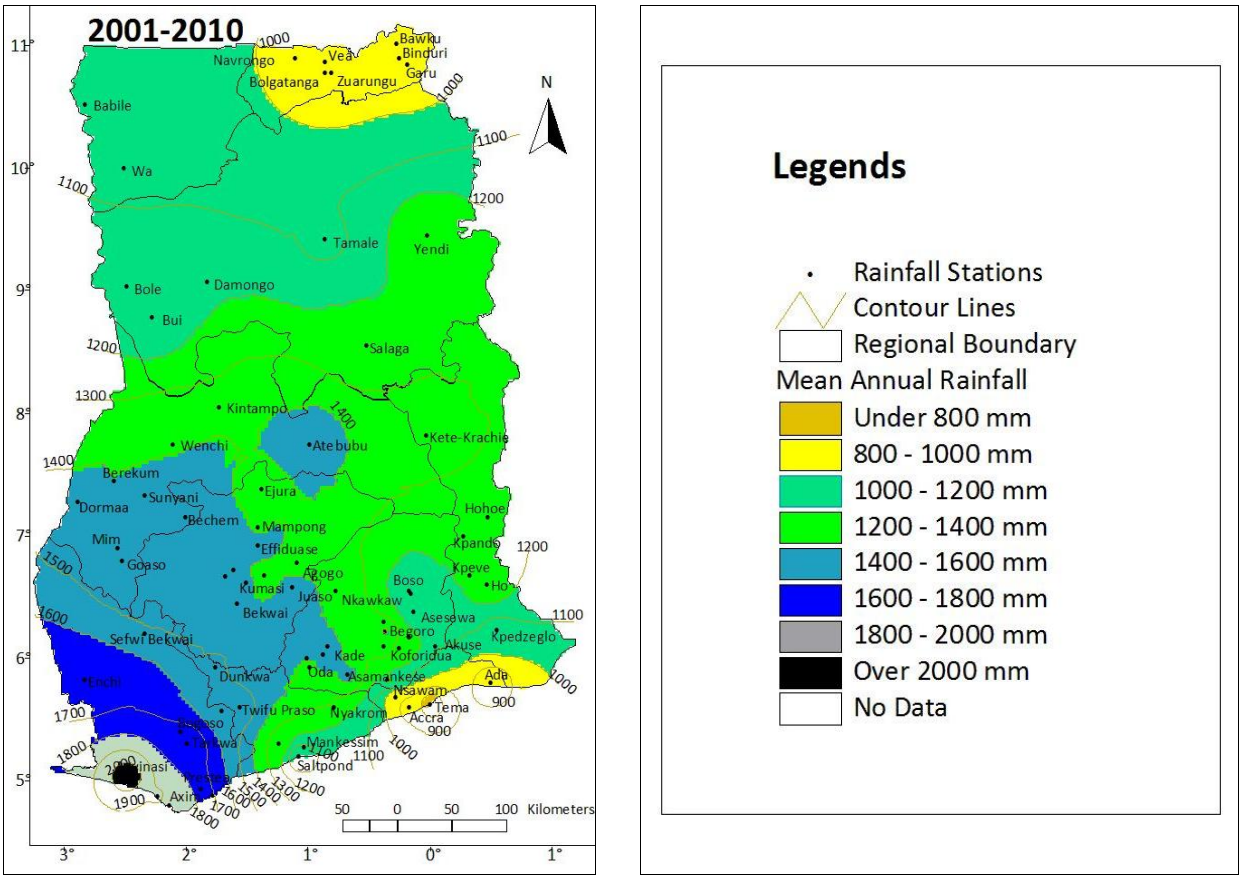


Fig. 5 Mean annual rainfall distribution and variability in Ghana for the period 1981-1990, 1991-2000 and 2001-2010

Fig. 5 also showed a general increase in rainfall amounts from north to south with the wettest area located in the extreme southwest (Western Region) where the mean annual rainfall is constantly over 1,600 mm. With the exception of the period 1991-2000, the mean annual rainfall in the extreme north is less than 1,000 mm. However, the driest areas are in Accra and Tema in the south-eastern coastal strip where the mean annual rainfall values are 741 mm and 625 mm, respectively.

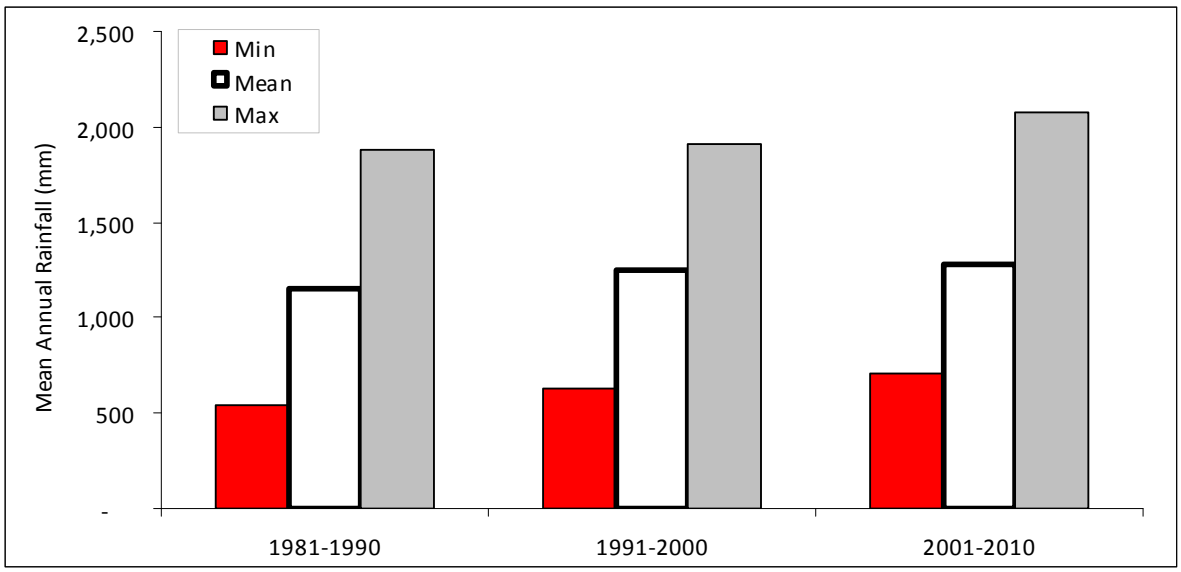


Fig. 6 Mean annual rainfall in Ghana for the period 1981-1990, 1991-2000 and 2001-2010

C. *Trend of mean annual rainfall amounts*

Fig. 6 shows a general increment in the trends of the mean, minimum and maximum annual rainfall in the country within the last three decades at decadal time interval. The mean annual rainfall for the 1981-1990, 1991-2000 and 2001-2010 are 1,150 mm, 1,250 mm and 1,281 mm, respectively. The values for 1991-2000 and 2001-2010 show increases of 8.6 % and 2.6 %, respectively, relative to the 1981-1990 value. Fig. 7 depicts inter-decadal annual rainfall at Navrongo, Kumasi, Accra and Axim. Generally, there is a slight increase in the mean decadal annual rainfall values for all locations.

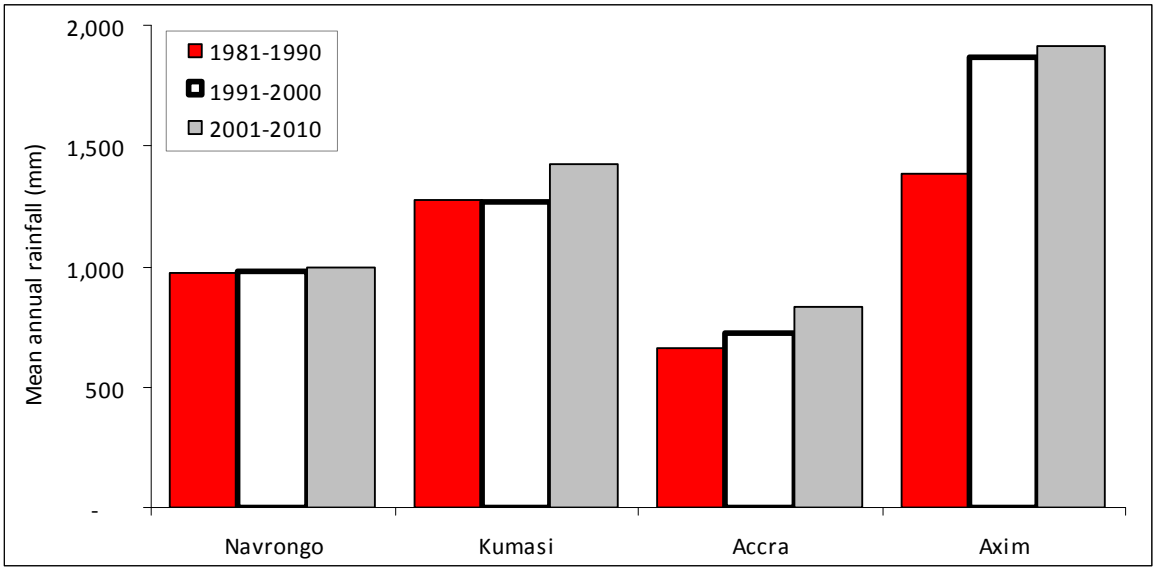


Fig. 7 Mean annual rainfall at Navrongo, Kumasi, Accra and Axim for the period 1981-1990, 1991-2000 and 2001-2010

CONCLUSION RECOMMENDATIONS

The study of rainfall variability in Ghana is carried out using mean annual rainfall at inter-decadal time intervals for the periods 1981-1990, 1991-2000 and 2001-2010 from 77 stations. Compared to the results of Anang (1997), there have been general declines in the mean annual rainfall for the past 30 years with high rainfalls shifting to the Western Region and low rainfall increasing in its distribution in the Upper East Region of Ghana. This can be an indication of global warming as a result of bad anthropogenic activities such as deforestation, overgrazing, urbanization and farming close to rivers and water bodies. However it have been deduced from the study that mean decadal rainfall amounts is on a gradual increase for the period 1981-2010, though the rate at which it is increasing is on a decline, i.e. from 8.6 % in 1991-2000 to 2.6 % in 2001-2010.

Understanding the inter-decadal and/or inter-annual variability and distributions of rainfall is important and useful for agricultural activities. We therefore recommend that farmers be assisted by GMet and agricultural extension officers to adjust to the inter-annual and/or inter-decadal rainfall variability and distribution in order to avoid total failure of crops. In view of rainfall uncertainty and even drought events, farmers are advised to consider adopting supplementary irrigation practices aside their sole reliance on rainfall. We also recommend that studies on rainfall variability be carried out in a continuous manner as and when new rainfall data is available in order to update such information for use by all.

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