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Precipitation Patterns in the Gambia from 1981 to 2020

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Abstract

The present study used composite analysis and rainy season definition to investigate rainfall patterns in The Gambia from 1981 to 2020. Rainfall dataset as observed by 10 meteorological stations scattered across The Gambia was used. Results showed that the highest single month rainfall ever recorded in The Gambia during the study period was observed in Sapu, in the eastern sector of the country. The station recorded a total rainfall amount of 767 mm in August, 1999, while the lowest single month rainfall ever recorded was 463 mm in September 2012. It was observed in Jenoi, a station situated in the western sector of the country. Climatological results showed that the study area experienced monomodal rainfall regime during the West African Monsoon, and that the southern part of the western sector region such as Sibanor tend to receive more rainfall compared to other regions of the study area. Part of the central region receives the least annual rainfall. The eastern sector of The Gambia received much of its rain from May to October with July - September as the peak of the rain season. During May - October, Sapu received the heaviest rainfall while Fatoto received the least amount. Results also show that July - September is the period when significant amounts of rainfall are received over the eastern sector of the study area. While May and October are both transitional months, the eastern sector of the study area receives more rains in October than in May. The western sector of the study area, on the other hand, received much of its rain from June to October with July - September as the peak of the rain season. During June - October, Sibanor received the heaviest rainfall while Jenoi received the least amount. The results also show that July - September is the period when significant amounts of rainfall are received over the western sector of the study area. Although June and October are both transitional months, the western sector receives more or less the same rain amounts in June and October. Results further found that, to avert losses associated with excess or deficit in crop water requirement, in the eastern sector, crops with high water requirement should be grown before August as maximum rainfall is observed in August, whereas crops with minimum water requirement should be grown in May or October, that is when minimum rainfall is experienced. In the western sector, on the other hand, crops requiring high water amount should be grown before August or September when maximum rainfall is recorded in the sector, whereas crops with minimum water requirement should be grown in June or October. This study will help create awareness on the erratic rain seasons due to Climate Change, and to provide farmers with information on rainfall distribution in The Gambia to avert losses and impacts associated with water deficit or excess on society, agriculture, and the environment.

Keywords: rainfall; composite analysis; rainy season; monsoon; monomodal; The Gambia

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Introduction

Precipitation is one of the most important meteorological variables in West Africa where economies mainly depend on rain-fed agriculture (Nangombe et al., 2018). This is due to the fact that precipitation deficit or excess usually have huge impacts on agriculture, society, and the environment. Thus, calling for the need to study precipitation concentration in West African countries. In West Africa, the summer monsoon accounts for more than 75 percent of the total annual rainfall (Akinsanola & Zhou, 2018a). The West African Summer Monsoon (WASM) is a highly determining factor of socio-economic development activities over the region (Janicot et al., 2011). Researchers have linked the inter-annual rainfall timescales in West Africa to El Niño-Southern Oscillation (ENSO) (beyond the scope of this study), by stating that ENSO is the most important sea surface temperature pattern influencing the West African Monsoon dynamics (Joly and Voldoire, 2009). It has been found that the precipitation patterns over West Africa are experienced in the location of the monsoon trough (Nicholson, 2008, 2009). Based on findings from several studies over West Africa, the variation in the WASM rainfall is controlled by various and complicated processes, and is also sensitive to Global Warming (Akinsanola & Zhou, 2018a; Akinsanola et al., 2015; Sylla et al., 2013; Nicholson, 2013; Sultan & Janicot, 2003). Precipitation in West Africa is characterized by the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ), also referred to as Inter Tropical Discontinuity (ITD) over West Africa. During boreal summer, the ITCZ propagates northward reaching about 20oN at the peak of the rainfall season, that is in August, whereas during winter the ITCZ is located along the Gulf of Guinea Coast. Over West Africa, during boreal summer, surface airflow is peaked by two jets, namely: the Tropical Easterly Jet (TEJ) and African Easterly Jet (AEJ).

It has been established that rainfall variability in the Sahel region of West Africa is very high and the region had experienced severe droughts in most of the 1980s. The current debate is some studies, for example (Sanogo et al. 2015; Giannini, 2015) have stated that rainfall in the Sahel has increased after the severe droughts of the 1980s. On the other hand, some researchers have stated that the droughts continued to be experienced in the Sahel region through the 1990s (L'Hote et al., 2003; Nicholson et al., 2000). Thus, the need to study rainfall distribution over individual Sahel countries in order to have a clear picture of rainfall patterns. In West Africa and in this study, precipitation and rainfall are used interchangeably.

Located in the Western Africa region, The Gambia is a small country, and particularly highly vulnerable to Climate Change impacts. The Gambia's vulnerability to climate change impacts stems from: a high reliance on climate-sensitive economic activities such as farming, livestock rearing, fisheries and forestry; the presence of large population clusters, the low capacity of the country's social and ecological systems to cope with climatic extremes (Gizaw & Gan, 2017). Of great concern is the projection that during the rainy season in West Africa, the central Sahel is going to get wetter, while the western Sahel is projected to get dry (IPCC, 2007a). Although with medium confidence, it has also been projected that with global warming of 2o C, West Africa is to experience arid, drier, and more drought-prone climate, and with 3o C global warming, meteorological drought frequency will increase, and their length will double from about 2 – 4 months in the western Sahel (Adelekan et al., 2022). Situated in the western Sahel region, The Gambia is one of the countries expected to be affected by these projections. Given the fact that the small West African country's economy is dominated by extensive rain-fed agriculture, therefore, analysis of long historical rainfall data is imperative in order to: (1) provide robust information on the distribution of precipitation; (2) better prepare farmers on extreme events mitigation to avert agricultural losses. Social-economic sectors such as water management, agriculture and infrastructure development are affected by the average amount and the temporal distribution of precipitation, as excessive precipitation and lack of precipitation both have adverse effects on society (Sadiq & Qureshi, 2014). Therefore, understanding the distributions of precipitation makes it possible to estimate the likelihood of rainfall being within a specified range. In order to better prepare for future extreme events, the amount and seasonal distribution of rainfall are the most important factors to consider when looking at rainfall across The Gambia. The goal of this paper, therefore, is to focus on The Gambia and examine precipitation distribution for the period 1981 - 2020.

The remainder of this paper is designed as follows; section 2 covers description of the study area, the data, and the methodology in the study, section 3 discusses the findings of the study, and section 4 gives the conclusion and recommendations.

Study area, data and methodology

Study area

The Gambia is the smallest country on mainland Africa. It is bounded by latitudes of 13° to 14° N and longitudes of 17° to 14° W (figure 1), and situated on both sides of the lower reaches of the river Gambia. The river Gambia flows through the center of the country, thereby dividing the country into the north and south banks, and empties into the Atlantic Ocean. The Gambia is characterized by low land features, and is surrounded by Senegal on three sides, except to the west where about 80km of coastline on the Atlantic Ocean marks the western border of the country. The Gambia's climate is characterized by one short rainfall regime, that is monomodal, due to the north-south migration of the Inter-Tropical Convergence Zone. The West African monsoon brings rain to The Gambia. Rain is observed between June and October (Gu & Adler, 2004; Gianini et al., 2003). No part of the country is desert.

Data

In this paper, monthly rainfall data from 1981 to 2020 over The Gambia as observed and archived by 10 meteorological stations (figure 1c) spread across The Gambia, and overseen by The Gambia Meteorological Department was studied. The Gambia Meteorological Department is a government technical department in charge of weather and climate monitoring in The Gambia. At the time of this research, it runs a network of 10 meteorological stations widely spread across The Gambia. 10 meteorological stations with quality-controlled data have been used in this study. These stations have complete and continuous data records and are distributed widely across the country.

Recently, several gridded data sets of daily/monthly precipitation based on satellite products have become available for the entire African continent. In most of these data sets the satellite products have actually been merged with information based on rain gauge data. These gridded data sets, however, provide quite different representations of daily/monthly precipitation behavior (Sylla et al., 2013), hence, giving rise to a certain degree of uncertainty. Therefore, the value of such data sets for the quantitative evaluation of various characteristics of rainfall beyond the basic ones is limited. Due to these reasons, we have used rain-gauge measurement data in this study. The network of rain-gauges shown in figure (1c), are sufficient to study the synoptic meteorological conditions of The Gambia. In the present study, we divided the study area into two sectors (western and eastern) (figure 1c).

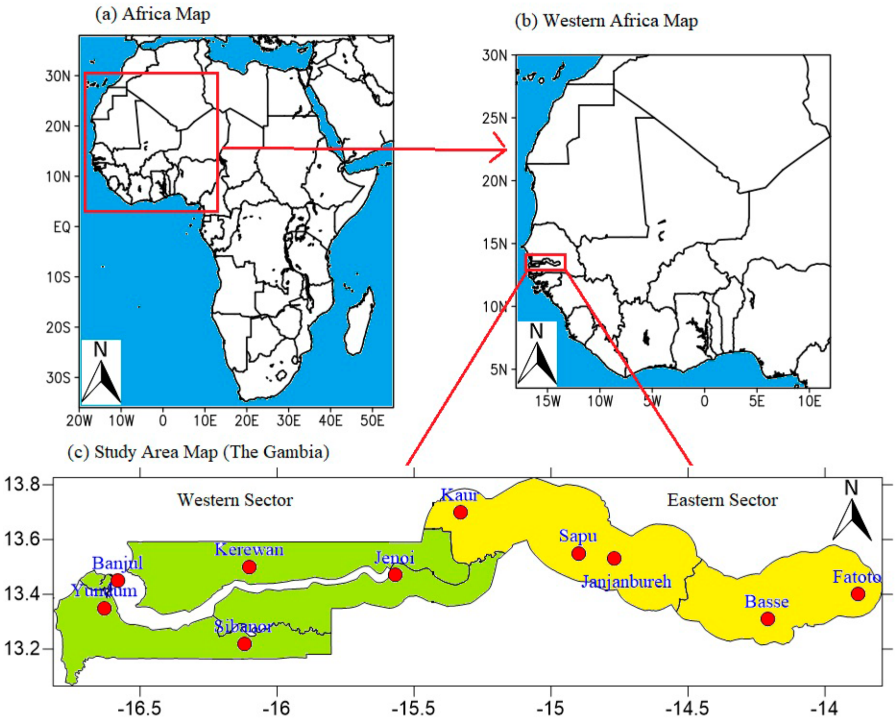

Figure 1. The Geographical location of (a) Western Africa on the map of Africa (red rectangle), (b) The Gambia in Western Africa (red rectangle), (c) the study area showing meteorological stations (red dot), eastern sector (yellow shade), and western sector (green shade)

Methodology

Composite Analysis

In this study, in order to establish the spatial rainfall distribution, composite analysis was used. Composite analysis is defined as the identification and averaging one or more categories of fields of a variable which are selected based on their association with main conditions. And then use the results of the composites to generate hypotheses for the distribution of rainfall geographically, temporally, and seasonally which may be associated with the individual scenarios (Folland et al., 2009). A number of authors, including Libanda et al. (2015); Koumare, I. (2014); Ogwang et al. (2012); Ininda (1995); Okoola (1999) have used composite methods in their analyses over Southern, Western, and Eastern Africa, respectively.

Rainy Season Definition

In the present study, we defined the rainy season at each synoptic station on the basis of monthly precipitation following the method suggested by Liebmann and Marengo (Liebmann and Marengo, 2001). As a method to view precipitation season they defined the rainfall accumulation quantity A for a given calendar day of the year as:

$$A(month) = \sum_{n=1}^{month} R(n) - \bar{R} \cdot month \tag{1}$$

Where *R(n)* is the climatological monthly precipitation as a function of the month of the year and is the climatological annual mean monthly precipitation.

Should the rainy season at a given station be considered as the period during which climatological monthly precipitation exceeds its annual average, then an upward slope of the total quantity indicates the onset of the rainy season, while a downward slope indicates the end. It is worth noting that the definition of the rainy season used here is local, as it is based on the climatology of monthly precipitation at a given station.

Results and discussion

In this chapter the results obtained from the methods used to address the aims of the present study are presented and discussed.

Table 1 presents the latitudes and longitudes of the meteorological stations used to gather rainfall data from 1981 – 2020.

Table 1. Location of the Meteorological Stations used

Name	Latitude (°N)	Longitude (°W)
Banjul	13.45	16.58
Basse	13.31	14.21
Fatoto	13.40	13.88
Janjangbureh	13.53	14.77
Jenoi	13.47	15.57
Kaur	13.70	15.33
Kerewan	13.50	16.10
Sapu	13.55	14.90
Sibanor	13.22	16.12
Yundum	13.35	16.63

Spatial characteristics of 1981 – 2020 rainfall

Figure 2 displays the average seasonal rainfall over The Gambia. From the figure, it can be seen that the southern part of the western sector region such as Sibanor tend to receive more rainfall compared to other regions. This is likely because Sibanor is located in a thick vegetation cover zone in The Gambia. Part of the central region receives the least annual rainfall in the study area.

The eastern sector of The Gambia receives much of its rain from May to October with July - September as the peak of the rain season. This means that the findings of Gu and Adler (2004), and Gianini et al. (2003) that rain is observed between June and October did not capture the rain season in the eastern sector of The Gambia where most farming activities are carried out. As can be seen from the composite of the eastern sector of the country below (figure 3a), during May - October, Sapu received the heaviest rainfall while Fatoto received the least amount. The observed high rainfall amount recorded in Sapu compared to other stations in the eastern sector is due to its close proximity to the river Gambia, whilst the low rainfall amount observed in Fatoto is because it is the farthest station inland, therefore it has the farthest proximity from a water body. The results also show that July - September is the period when significant amounts of rainfall are received over the eastern sector of the study area. From 1981 – 2020, all areas received less than 50 mm of rainfall during the month of May. While May and October are both transitional months, the eastern sector of the study area receives more rains in October than in May.

The western sector of the study area, on the other hand, receives much of its rain from June to October with July - September as the peak of the rain season. This supports the findings of Gu and Adler (2004), and Gianini et al. (2003). Also, as can be seen from the composite of the western sector of the study area below (figure 3b), during June - October, Sibanor

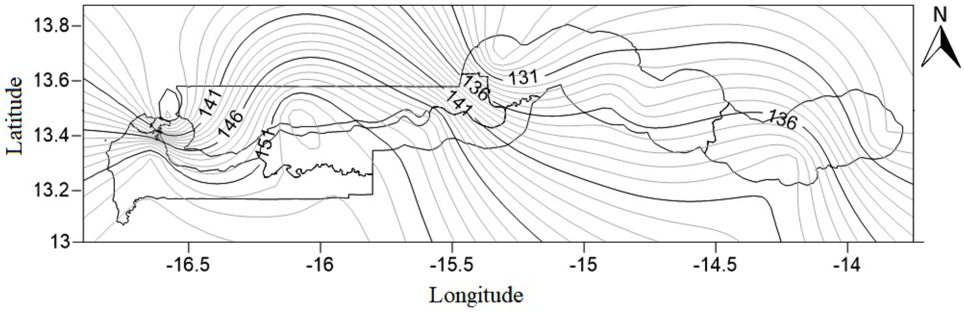

Figure 2. Mean seasonal rainfall (mm) distribution over The Gambia

received the heaviest rainfall while Jenoi received the least amount. These findings support those of Nicholson (2013), which stated that rainfall in the Sahel reduces towards the Sahara Desert. The results also show that July - September is the period when significant amounts of rainfall are received over the western sector of the study area. From 1981 – 2020, all areas received less than 100 mm of rainfall during the month of June. While June and October are both transitional months, the western sector of the study area receives more or less the same rain amounts in June and October.

During 1981 – 2020, as can be seen from Table 2, all stations recorded high amounts of rainfall between July - September and a decline in October. This trend confirms the life cycle of the Inter Tropical Convergence Zone (ITCZ). The ITCZ is an east-west oriented low-pressure region near the equator where surface Northeasterly and Southeasterly trade winds meet (Premaratne et al, 2021). It is known as the Inter Tropical Discontinuity (ITD) in West Africa by some scientists; it is the northern edge of the Western African Monsoon (Janicot, 1992). Its movement north and south of the equator is a consequence of the earth's rotation around the sun (Nicholson, 1981). The ITCZ is the dominant rain producing mechanism over Western Africa. Over The Gambia it remains inactive until early or mid-May, reaching its peak in August giving the Gambia its main rains before it propagates southwards.

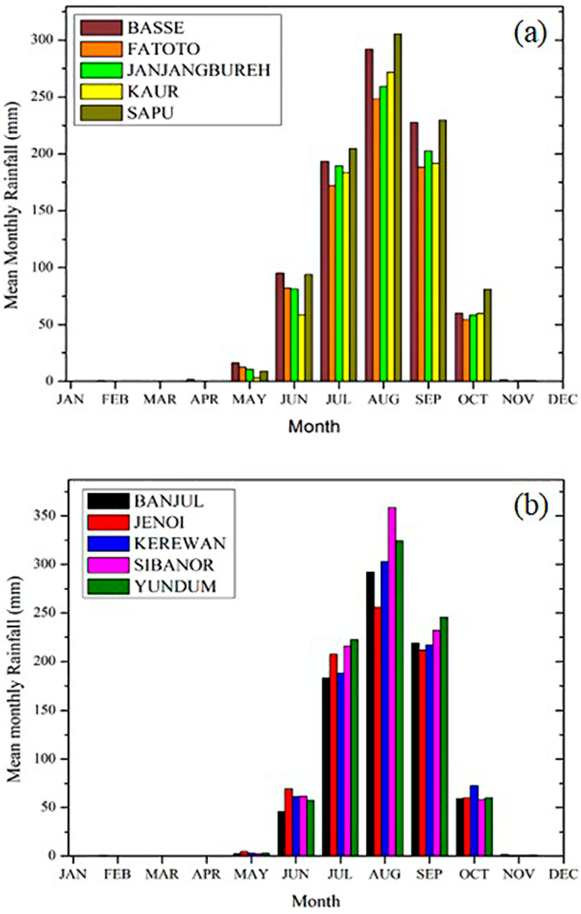

Figure 3. Mean monthly rainfall over the (a) eastern sector, (b) western sector of The Gambia

Table 2. Mean monthly Rainfall (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Banjul	0.5	0.7	0.0	0.0	2.5	45.7	182.9	292.0	218.9	59.3	1.4	0.2
Basse	0.2	0.3	0.1	1.6	16.3	95.3	193.5	291.8	227.4	60.0	1.4	0.2
Fatoto	0.1	0.2	0.1	0.2	12.3	82.3	172.1	248.0	188.4	54.6	0.3	0.2
Janjangbureh	0.2	0.0	0.1	0.0	10.4	81.3	189.5	259.3	202.7	58.3	0.5	0.0
Jenoi	0.0	0.0	0.0	0.0	4.5	69.1	207.3	255.7	211.5	60.1	0.9	0.2
Kaur	0.1	0.1	0.0	0.0	3.4	58.6	183.3	271.7	191.8	60.0	0.5	0.0
Kerewan	0.4	0.6	0.0	0.0	2.8	61.1	188.1	302.8	217.0	72.4	0.8	0.1
Sapu	0.0	0.1	0.0	0.0	8.7	94.1	204.4	305.1	229.6	81.0	0.6	0.1
Sibanor	0.1	0.2	0.0	0.0	2.4	61.8	215.7	358.6	232.1	58.0	0.8	0.3
Yundum	0.3	0.5	0.0	0.0	2.7	57.4	222.3	324.2	245.9	60.2	1.2	0.3

Maximum and Lowest Rainfall, and Standard Deviation

In order to observe guidelines of the United Nations' Food and Agricultural Organization (FAO) that different crops have different water requirement, and different growing period (number of days from sowing to maturity) in The Gambia, analysis of maximum and lowest rainfall, and standard deviation is done for individual stations across the study area to: (1) understand rainfall climatology at individual stations, and (2) provide farmers with robust information on the type of crops to grow and when to grow them in different regions across The Gambia based on the maximum and minimum, and standard deviation of rainfall in that area. This will go a long way in reducing losses associated with above (below) required water by different crops.

Individual station rainfall climatology during the period of study for the eastern and western sectors is shown in figures 5 (a – e) and figures 6 (a – e), respectively. The figures show the maximum rainfall record-

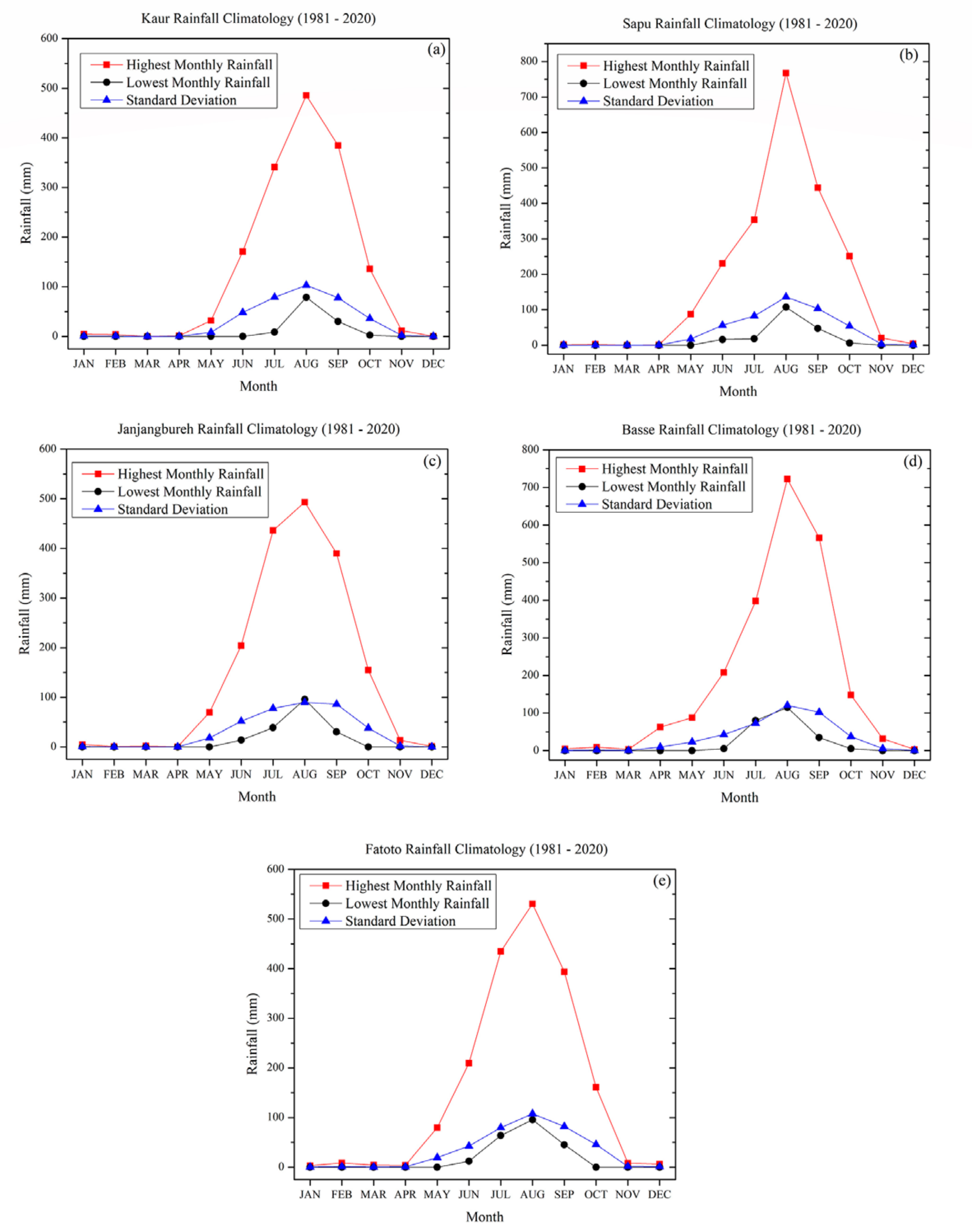

Figure 4. Rainfall variability at individual stations (Eastern Sector)

ed, standard deviation, and lowest rainfall recorded. The highest monthly rainfall received on record for Banjul during the study period was 662 mm in 2010 in the month of September (Table 3). Kerewan recorded its highest monthly rainfall in August 1988 which amounted to 680 mm. The highest monthly rainfall reported in Kaur was 486 mm in the month of August, 1982. 493 mm is the highest monthly rainfall received during the 1981 – 2020 period in Janjangbureh, in August 1999. Basse received its maximum monthly rainfall in August 1999 which amounted to 723 mm. Fatoto reported 531 mm in August, 1999 during the period of study. In August, 1999, Sapu received 767 mm as its maximum monthly rainfall during the study period. Jenoi recorded its highest monthly rainfall in September 2012 which amounted to 463 mm. The highest monthly rainfall reported in Sibanor was 632 mm in the month of August, 1988. 654 mm is the highest

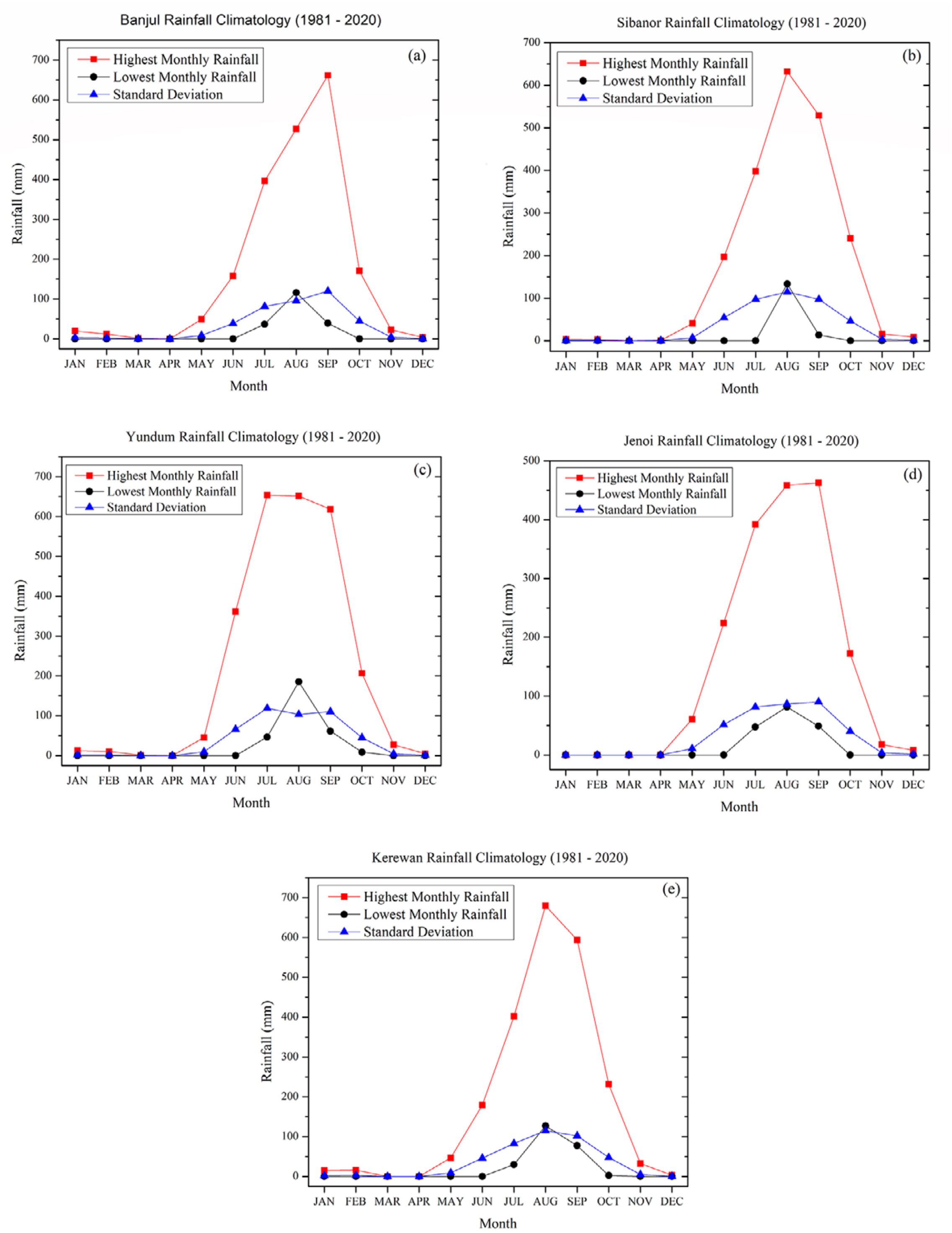

Figure 5. Rainfall variability at individual stations (Western Sector)

monthly rainfall received during the 1981 – 2020 period in Yundum in July, 2009.

In the eastern sector, to avert losses associated with excess (deficit) water requirement, crops with high water requirement should be grown before August, because maximum rainfall is experienced in August; whereas crops with minimum water requirement should be grown in May or October as that is when minimum rainfall is experienced. On the other hand, in the western sector, to avert losses associated with excess (deficit) water requirement, crops with high water requirement should also be grown before August or September is when maximum rainfall is recorded, whereas crops with minimum water requirement should be grown in June or October because that is when minimum rainfall is observed.

Table 3. Highest station rainfall received during the study period

Station	Rainfall (mm)	Year	Month
Banjul	662	2010	September
Basse	723	1999	August
Fatoto	531	1999	August
Janjangbureh	493	1999	August
Jenoi	463	2012	September
Kaur	486	1982	August
Kerewan	680	1988	August
Sapu	767	1999	August
Sibanor	632	1988	August
Yundum	654	2009	July

Conclusion

This study investigates rainfall patterns in The Gambia by considering periodic interval of 40 years (1981-2020). The study domain experiences monomodal rainfall regime during the West African Monsoon season. Climatologically, the eastern sector of The Gambia receives much of its rain from May to October with July - September as the peak of the rain season. The western sector of the study area, on the other hand, receives much of its rain from June to October with July - September as the peak of the rain season. Hence, rainfall onsets earlier in the eastern sector than in the western sector. The southern part of the western sector region such as Sibanor tend to receive more rainfall compared to other regions of the study area. Part of the central region receives the least annual rainfall in the study area during the study period. The Gambia is particularly affected by the movement of the ITCZ which brings rains when it enters the Gambia from the South in May as it traverses to the North of West Africa, reaching its most northern peak in August.

The result from maximum and minimum, and standard deviation of rainfall both in the eastern and western sector of the study area show that stations across the country record different amount of rainfall in different months. In the eastern sector, crops with high water requirement should be grown before August, this is when maximum rainfall is experienced, whereas crops that require minimum water should be grown in May or October. On the other hand, in the western sector, crops that require high water amount should be grown before August or September as this is when maximum rainfall is recorded, whereas crops with minimum water requirement should be grown in June or October.

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