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Estimation of Arrival and Withdrawal Date of Rainy Season in Bangladesh

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Abstract
The arrival and withdrawal of rainfall in a region are important for the local community's agriculture, life, and livelihood. This paper explores the temporal and spatial variation of the arrival and withdrawal date of the rainy season in Bangladesh using the weather station's daily rainfall data from 1983 to 2017. Twelve weather stations of Bangladesh were selected for this study to represent the country. Following Ahmed and Kim (2003), the arrival/withdrawal date of the rainy season was determined by the first day/last day of the rainy season, considered at least three consecutive days of 5mm or more rainfall. The results showed that the length of the rainy season and the quantities of seasonal rainfall are highest in the eastern zones and lowest in the western zones of Bangladesh. In the context of monthly rainfall variation, July (551mm) is the highest month of rainfall, while October (203mm) is the smallest month of rainfall. From eastern zones to western zones, the arrival date of the rainy season first starts on average 15 May in the eastern zones, 20 May in the central zones, and 30 May in the western zones of Bangladesh, respectively. From 1983 to 2017, the withdrawal dates of the rainy season first ended in the western zones on average 1 October, then 4 October in the central zones, and lastly 9 October from the eastern zones. Considering previous literature, the arrival and withdrawal dates of the rainy season advanced 12 days all over Bangladesh and the duration of the rainy season and the seasonal rainfall also increased spatially and temporally. The variability of the rainy season in Bangladesh warning that the intensity and frequency of the remittent flooding during the rainy season have serious consequences on the human, financial, infrastructure, and food security of the region.

Keywords: Weather station, Climate, Climate Change, Seasonal variation.

Introduction

Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, adequately hot temperature, and high humidity (Ahmed, 1994). Therefore, three meteorological weather seasons are recognized in Bangladesh –summer, monsoon, and winter from the climatic perspective (Ahmed and Karmakar, 1993; Mannana et al., 2015). The summer season is hot and humid and extending from March to June, the rainy season is cool and extending from June to October, and the winter season is dry and extending from October to March (Ahmed, 1994; Khatun et al., 2016).

The rainy season is the most important feature that controls the climate in Bangladesh. During this season, it accounts for about 75-80 % of the country's annual rainfall (Stern and Coe, 1982). The variability of the onset and ends date of the rainy season has great impacts on agriculture, fisheries,

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power generation, water resources, ecosystem, and economics in Bangladesh (Ahmed, 1994; Ahmed and Karmakar, 1993). The fertility of cultivated land, as well as the solidity of land resources, also depends on the pattern of rainfall during the rainy season (Khatun et al., 2016; Mannana et al., 2015). Ahmed and Kim (2003) summarise the main mechanism of the rainfall in Bangladesh during the summer monsoon/rainy season which is provided by the tropical depressions, also known as the monsoon depressions in the Bay of Bengal region.

The arrival and withdrawal dates of the rainy season differ from year to year and also vary regionally. The eastern part of Bangladesh plays a vital role the socio-economic development and the ecological balance for its topological features like hills, rivers, wetlands, floodplains, etc. (Rokounzzaman et al., 2018). As the starting of the rainy season and the ending of the rainy season may affect many economic and social activities and studies of the rainy season can predict the arrival and withdrawal date of the rainy season (Ahmed and Karmakar, 1993; Ahmed and Kim, 2003, Mannana et al., 2015).

Only a few types of research about rainfall patterns during the rainy season have been studied in Bangladesh. Ahmed and Karmakar (1993) Observed the variability of arrival and withdrawal dates of the summer monsoon in Bangladesh and (Ahmed, 1994) revealed the relationship with monsoon onset dates. Summer monsoon rainfall trend in Bangladesh did not show any changing pattern; neither increasing nor decreasing (Rahman et al., 1997). Ahmed and Kim (2003) also analysed the patterns of daily rainfall in Bangladesh during the summer monsoon season: case studies at three stations. Another work-study of the rainfall variability and changes in Bangladesh during the last fifty years was analysed (Shahid, 2012).

This study estimates the changing pattern of arrival and withdrawal date of the rainy season in Bangladesh using station rainfall data of 35 years up to 2017 to check the consistency with previous studies (Ahmed and Karmakar, 1993; and Ahmed and Kim, 2003).

Materials and Method

Data and region

Geographically Bangladesh extends from 20º34′N to 26º38′N latitude and from 88º01′E to 92º41′E longitude has a subtropical- humid climate. Except for the hilly southeast, most of the part has homogenous topography. Bangladesh Meteorological Department (BMD) is the sole agency who has 47 meteorological stations over the country for measuring the daily rainfall and other weather parameters. However, the daily rainfall data over fifty years are available at only nineteen stations (1958-2017). Among them, for this study, twelve stations were selected which are divided into seven regions, i.e., North-Eastern (Sylhet, and Srimangal), South-Eastern (Cox's Bazar, and Teknaf), Central-Plain (Dhaka), North-Central (Mymensingh), South-Central (Barisal, and Patuakhali), North-Western (Rajshahi, and Rangpur), South-Western (Jessore, and Khulna), to represent whole Bangladesh.

To work with this recorded data, the considerable problems are missing data in some stations in some years. To identify the rainy season's accurate arrival and withdrawal date, the missing data were calculated by extreme check values. Although the climate areas are always changing and it is

not so easily detectable the changing pattern so the observation of rainfall data can give some idea to predict the changing the patterns of rainfall due to climatic action.

Following Ahmed and Karmakar (1993) method, both arrival and withdrawal date of rainy season were calculated. The arrival date of the rainy season was determined by the first day of the rainy season, considered at least three consecutive days of 5mm or more rainfall where the winds induced by the southerly and south-westerly. Moreover, the withdrawal date is also determined as the last day of the rainy season of at least three consecutive days of 5mm or more rainfall after the prevailing wind changes from southerly and south-westerly to northerly and north-westerly. The statistical calculation of arrival date and withdrawal date of the rainy season and their duration, number of rain days, and the seasonal rainfall and their distribution and variability also determined from 1 May to 31 October by this study. Microsoft Excel and QGIS software were used for data analysis and map preparation respectively.

Results and Discussion

After data analysis, the arrival and withdrawal dates of rainy Season and its duration, number of rain days and seasonal rainfall in different regions are given in Table 1. For the ease of description, seven regions are united in three sections, such as the eastern zones, the central zones, and the western zones of Bangladesh.

Table 1: Statistics of the Arrival and Withdrawal Dates of Rainy Season and Duration, Number of Rain Days and Rainfall during Rainy Season in Bangladesh (1983-2017)

Sl. No.	Stations Name	Arrival date	Withdrawal date	Monsoon duration	Number of rain days	Seasonal rainfall (mm)
	North-Eastern					
1	Sylhet	8 May	8 Oct	153.51	126.03	3395.20
2	Srimangal	14 May	6 Oct	145.40	94.66	1815.86
	South-Eastern					
3	Cox's Bazar	20 May	9 Oct	142.86	95.43	3351.37
4	Teknaf	19 May	13 Oct	147.86	102.31	4033.71
	Central-Plain					
5	Dhaka	20 May	3 Oct	136.71	78.31	1599.09
	North-Central					
6	Mymensingh	19 May	3 Oct	138.37	84.17	1836.91
	South-Central					
7	Barisal	23 May	5 Oct	135.54	81.86	1693.40
8	Patuakhali	21 May	8 Oct	140.89	90.80	2209.54
	North-Western					
9	Rajshahi	16 Jun	27 Sep	103.74	59.86	1001.94
10	Rangpur	19 May	30 Sep	134.80	72.60	1883.40
	South-Western					
11	Jessore	21 May	28 Sep	120.43	71.69	1268.60
12	Khulna	4 Jun	9 Oct	127.74	76.83	1446.06
	Average	**22 May**	**4 Oct**	**135.65**	**86.21**	**2127.92**
	σ	**10**	**5**	**13.36**	**17.28**	**949.79**

The arrival date of the rainy season

The arrival date of the rainy season from 1983 to 2017 in Bangladesh illustrates in Figure 1 which describes that the rainy season first arrived in the eastern part (Sylhet, Srimangal, Cox's Bazar, Teknaf) of Bangladesh on average by 15 May, then moves towards the other side of the country and reaches the central part (Dhaka, Mymensingh, Barisal, Patuakhali) by 20 May and finally reached the western part (Rajshahi, Rangpur, Jessore, Khulna) of the country on 30 May where the standard deviation is 10 days. It takes 15 days to cover the whole country. The speed of onset of the rainy season is quite faster in the north-eastern and south-eastern zones of Bangladesh rather than in other parts of the country. After analysis of three stations daily rainfall data from 1968 to 1998, Ahmed and Kim (2003) found that the rainy season first arrives in the south-eastern zone on average June 2 and complete north-western zone by June 15.

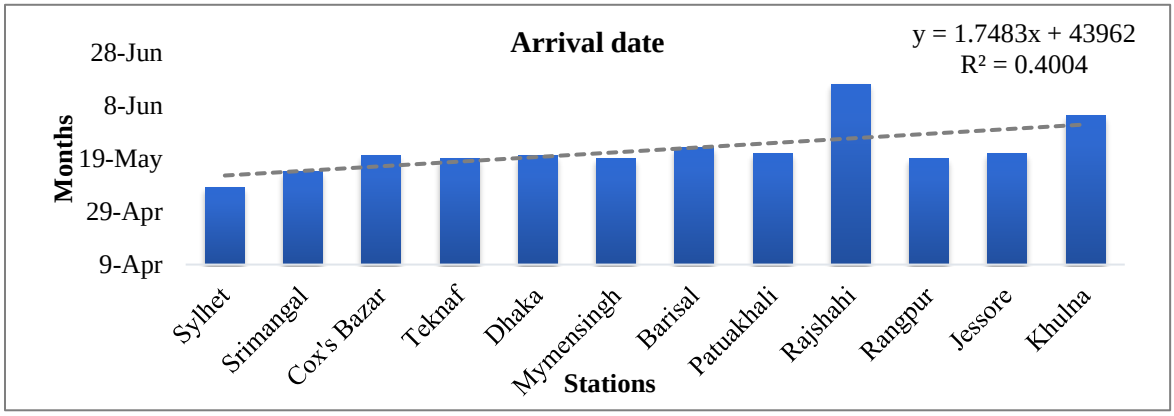

Figure 1: Arrival date of the rainy season in Bangladesh.

Withdrawal date of the rainy season

The first withdrawal date of the rainy season starts in the north-western and south-western parts of Bangladesh on 1 October then gradually retreats on 3 October in the central part, and lastly 9 October in the north-eastern and south-eastern parts of the country and this process takes 8 days to complete the withdrawal of the rainy season from Bangladesh (Figure 2) where the standard deviation is 5 days. The rainy season begins to withdraw from the north-western corner of the country, on average by September 28 which is similar to Ahmed and Kim (2003) where they found on 30 September.

Variability of rain days and monsoon duration

Variability of rain days and monsoon duration illustrate in Figure 3, where the number of rain days increases in the north-eastern parts of Bangladesh on average by 110 days and gradually decreases 84 days in the central part and 66 days in the north-western parts of the country. The average rain days 86 in overall Bangladesh and the standard deviation is 17 days. The monsoon duration is also increased in the north-eastern part 150 days and then gradually decreases 138 days in the central and finally 119 days in the south-western part of Bangladesh. And the average monsoon duration is 136 days and the standard deviation is 13 days.

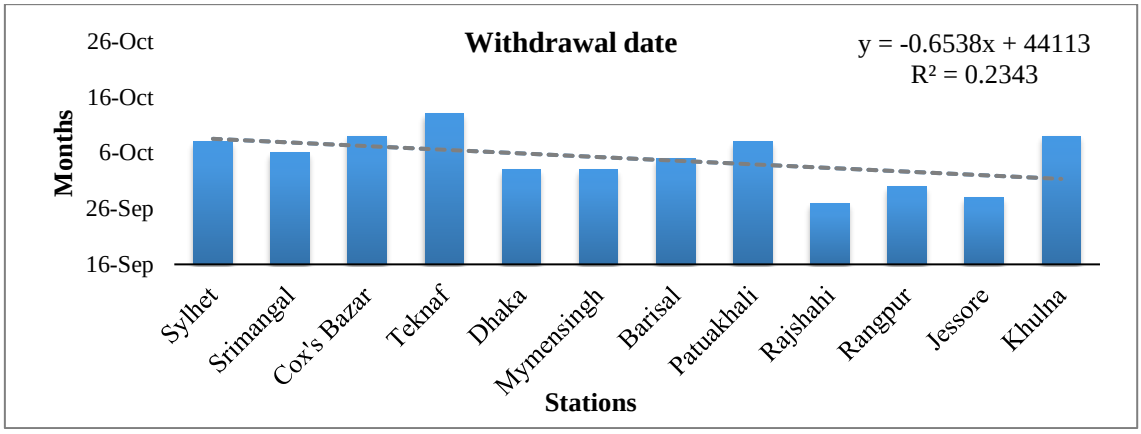

Figure 2: Withdrawal date of the rainy season in Bangladesh.

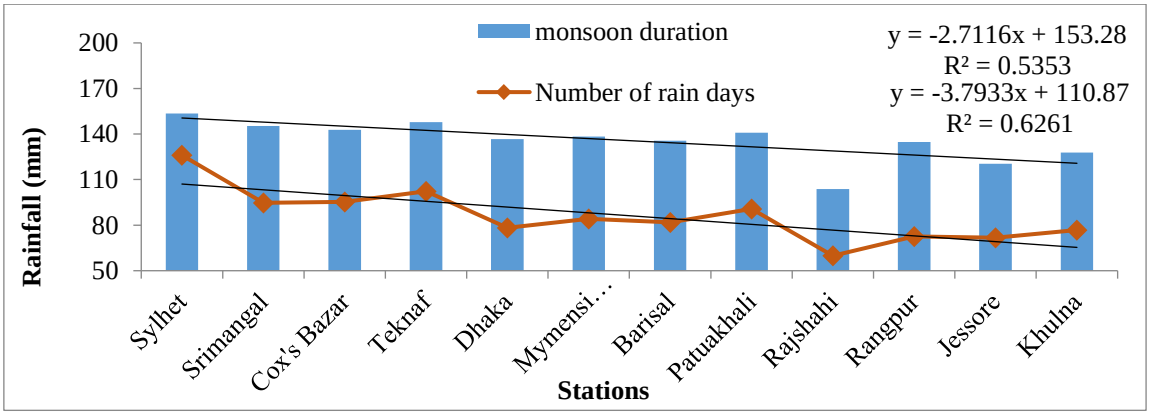

Figure 3: Monsoon duration and number of rain days in Bangladesh.

Variability of Seasonal rainfall

Figure 4 describes the seasonal rainfall in Bangladesh from 1983 to 2017. The seasonal rainfall is the highest in the north-eastern and south-eastern parts of Bangladesh on average 3149 mm then gradually lowest in the central part on average 1835 mm and north-western and south-western part on average 1400 mm. The mean seasonal rainfall over Bangladesh is 2128 mm and the standard deviation is 950 mm. The highest seasonal rainfall occurs in Teknaf 4034 mm and it is characterized as heavy rainfall sub-zone and the lowest seasonal rainfall occur in Rajshahi 1002 mm rainfall over the country.

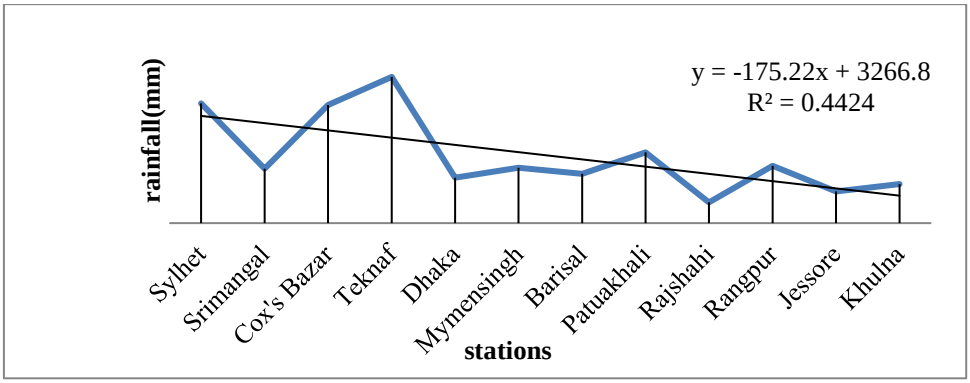

Figure 4: Seasonal rainfall in Bangladesh.

Table 2: Rainfall in mm during the rainy season from 1983 to 2017

Sl.	Stations	May	Jun	Jul	Aug	Sep	Oct	$\bar{X}$	σ
1	Sylhet	567	785	747	628	555	177	576	217
2	Srimangal	401	418	335	344	261	166	321	94
3	Cox's Bazar	356	839	992	704	383	250	587	300
4	Teknaf	293	1003	1176	928	452	290	690	391
5	Dhaka	274	317	396	314	316	189	301	68
6	Mymensingh	273	394	440	355	313	225	333	79
7	Barisal	199	376	428	349	279	200	305	95
8	Patuakhali	227	484	600	453	348	228	390	149
9	Rajshahi	90	209	300	247	246	131	204	79
10	Rangpur	214	430	466	367	350	226	342	104
11	Jessore	127	266	356	266	256	185	243	79
12	Khulna	159	291	374	326	286	169	268	86
	Average	**265**	**484**	**551**	**440**	**337**	**203**	**380**	**145**

The arrival and withdrawal date of the rainy season depends on the variability of the seasonal rainfall. Seasonal rainfall results based on monthly rainfall analysis. In the context of monthly rainfall variation for all the 12 weather stations, July is the highest month of rainfall, while October is the smallest month of rainfall. According to the ranking order of highest rainfall months categorized as July > June > August > September > May > October at Cox's Bazar, Teknaf, Dhaka, Mymensingh, Barisal, Patuakhali, Rajshahi, Rangpur, Jessore, and Khulna. Sylhet and Srimangal follow this trend but a little bit change (Table 2, Figure 5). Average rainy season rainfall in Bangladesh is shown in Figure 6 and spatial distribution of average monthly rainfall for the months of May, June, July, August, September, and October is given in Figure 7.

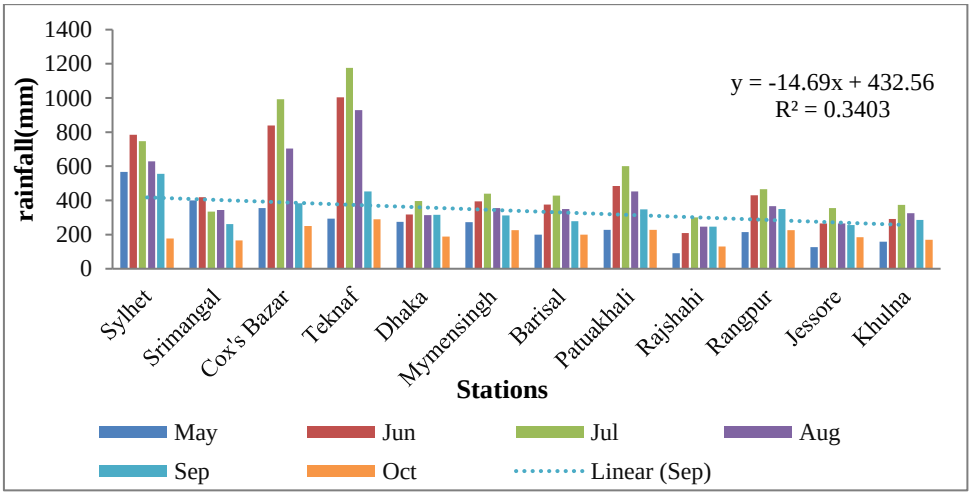

Figure 5: Mean monthly rainfall during the rainy season (1983-2017).

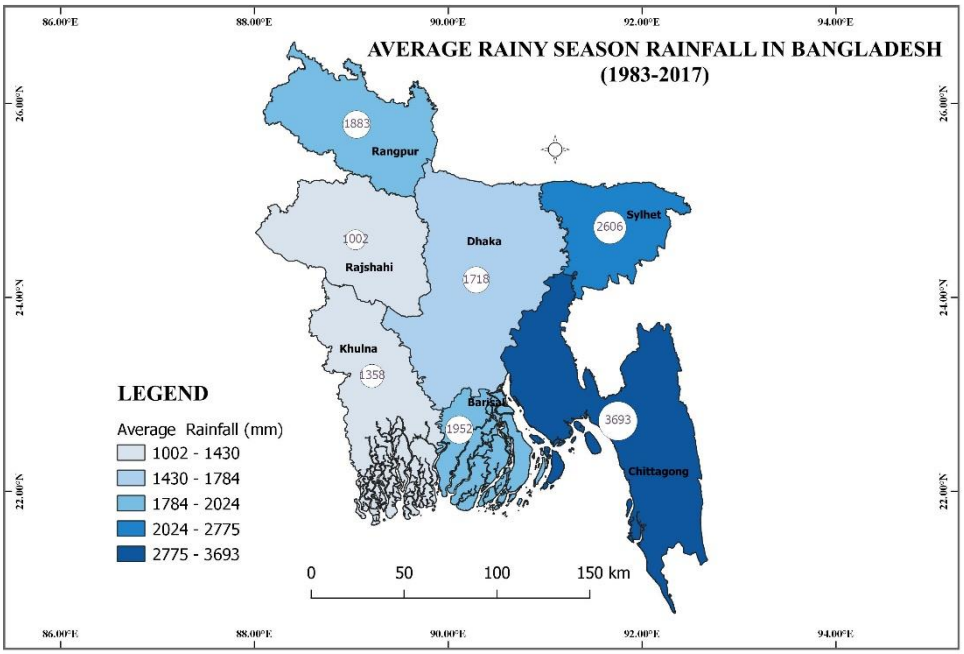

Figure 6: Average rainy season rainfall in Bangladesh.

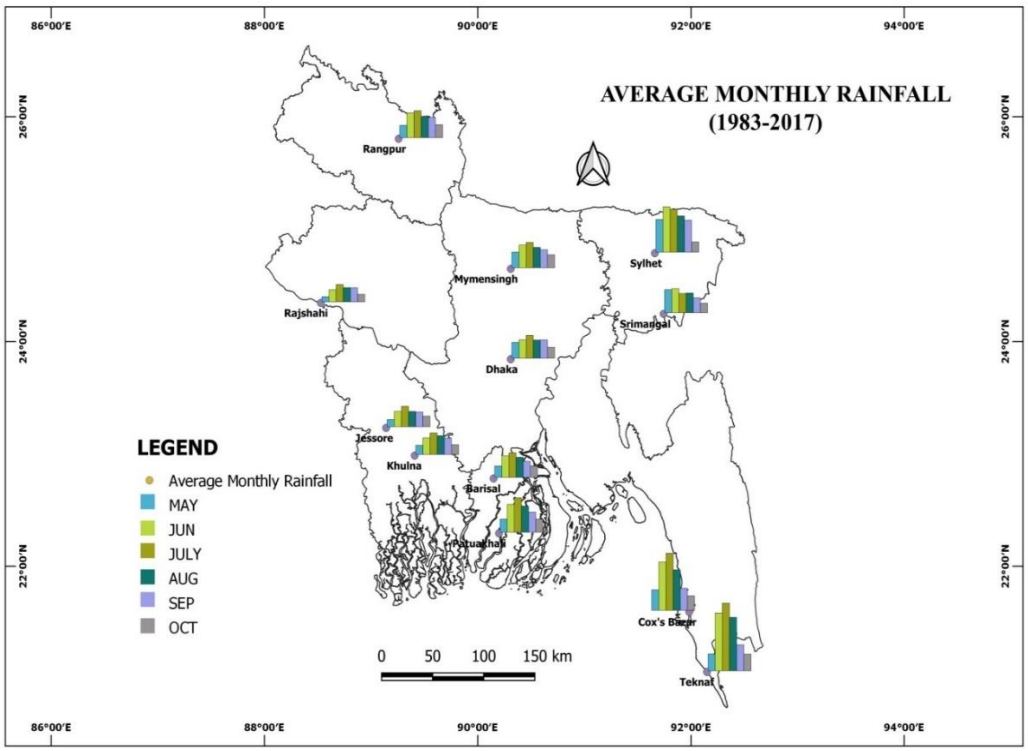

Figure 7: Spatial distribution of average monthly rainfall for May, June, July, August, September, and October for 35-year period (1983-2017).

A comparison table (Table 3) was prepared to show the similarity and dissimilarity of the findings with Ahmed and Kim (2003)'s study. Rainy season advancement and location of first arrival of rainy season are the major differences between the findings.

Table 3: Comparison of research findings with previous study

Issues	Ahmed and Kim (2003)	This study
Number of BMD stations	3	12
Year of investigation	1968-1998	1983-2017
First arrival date and location	June 2, South-eastern corner	May 11, North-eastern corner
First Arrival end date and location	June 15, North-western corner	June 2, North-western corner
First withdrawal date and location	September 30, North-western corner	September 28, North-western corner
Withdrawal completion date and location	October 17, South-eastern corner	October 11, South-eastern corner
Standard deviation of both the arrival dates and withdrawal dates	8 to 10 days	5 to 10 days
Average duration of rainy season	110 days in the west-central part to over 134 days in the south-east	119 days in the north-west part to over 150 days in the north-east

Issues	Ahmed and Kim (2003)	This study
Average number of rain days	60 days in the west-central part of the country to over 100 days in the northeast and southeast	66 days in the north-west part of the country to over 105 days in the northeast and southeast
Mean seasonal rainfall	about 1200 mm in the west-central part to over 3000 mm in the northeast and southeast	about 1300 mm in the south-west part to over 3100 mm in the northeast and southeast

Conclusions

This study concludes that the arrival and withdrawal dates of the rainy season are advanced 12 days all over Bangladesh from previous study and the duration of the rainy season and seasonal rainfall also increased spatially and temporally. This result indicates that rainfall response to global warming but does not decide that climate change affects the rainy season, from this result the climate model projection needs to be further explored.

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