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# Analysis of Arrival and Withdrawal Dates of Monsoon Rainfall in Dinajpur, Bangladesh

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**ABSTRACT**

This study was carried out to observe the spatial-temporal pattern of monsoon rainfall, acting as one of the major contributors to Bangladesh's water resources, particularly for agricultural purposes. Daily rainfall and prevailing wind speed for the period of 1986 to 2015 (April to November) of Dinajpur, Bangladesh were collected and analyzed to identify the trend, shifting pattern, and the past and probabilistic future arrival and withdrawal dates for 1 year out of 4, 10, and 25 years. It was revealed that the arrival and withdrawal dates were fluctuating between May to June and August to November, respectively. The mean arrival and withdrawal dates were evident on 3 June, and 27 September, respectively, and most of the dates were in the defined range of June to September. The early arrival dates were between 1 – 53 days except in 1992 (30 days later), and the late withdrawal dates were between 1 – 69 days except in 1987 and 2009 (5 and 10 days earlier). Finally, it was saliently appeared that the probabilistic early (21 May, 9 May, and 30 April) and late (12 June, 29 June, and 8 July) arrival dates are depicting the overall early start of monsoon, while the probabilistic early (13 September, 1 September and 23 August) and late (10 October, 22 October, and 1 November) withdrawal dates are representing the delayed overall withdrawal of monsoon rainfall in the targeted domain. To conclude, the findings of this study would be worthwhile for agricultural and regional planning purposes and, furthermore, for the management of floods and water resources in the North-western region of Bangladesh.



## Introduction

The occurrence of monsoon is a global incident and affects a vast area of Asia, Africa, and Northern Australia, covering more than 50% of the world population (Moley and Shukla 1987). The sudden changes in normal circulation from winter to summer are the primary reason for the evolution of season in South Asia (Matsumoto 1992; Murakami and Matsumoto 1994). It generally takes place in May and June, adjoining with the arrival of the Asian monsoon (Krishnomurti *et al.,* 1985; Hirasawa *et al.,* 1995). Bangladesh is one of the largest deltaic countries in the world, situated in South Asia. Consequently, the climatic condition of this country is precarious and changing day by day. This country is moreover vulnerable to climate change (Khatun *et al.,* 2016), prevailing sub-tropical climate. During monsoon, 75-80% of rainfall occurs in this country, which is the heaviest in the world (Ahmed and Kim 2003). Previous studies (Choudhury *et al.,* 1997; Quadir *et al.,* 2001; Ahasan *et al.,* 2010) revealed that precipitation in Bangladesh has increased during recent decades. The change of rainfall pattern and temperature is considered to measure climate change in a particular region (Alam and Sarker 2014). Global warming is responsible for changing the regional rainfall (Rodriguez-Puebla *et al.,* 1998; Gemmer *et al.,* 2004). Consequently, Bangladesh's rainfall pattern is changing (Hulme *et al.* 1998; Lambert *et al.,* 2004; Islam *et al.,* 2010).

Agriculture is the backbone of our economy, and it exceedingly depends on monsoon rainfall (Ahasan *et al.,* 2010). As Bangladesh is in the monsoonal territory, her people's life and subsistence rely directly or indirectly on the monsoon rainfall (Ahasan *et al.,* 2010; Mannan *et al.,* 2016). About 63% of the country's total population is dependent on agriculture for their livelihood. The fertility condition of agricultural land depends highly on the monsoon's behavior (Mannan *et al.*, 2016). The rainfall also helps to rejuvenate the environment. On the contrary, inconstancy in the arrival and withdrawal of monsoon and the volume of rain during the monsoon season has a significant effect on water resources for

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electricity, farming, economics, ecosystems, and fisheries (Khatun *et al.,* 2016). For the bereft of rainfall and shortage of irrigation water, drought and '*monga*' (famine) frequently occur in the northwestern hydrological zone (like Dinajpur) of Bangladesh. As a result, the amount of rice and wheat production decreases remarkably. Excessive rainfall brings floods that harm crop yield. Moreover, heavy monsoon rainfall often brings flood disasters, which is a significant problem for Bangladesh (Ohsawa *et al.*, 2000). Sometimes floods reach extreme stages, such as those of 1987, 1988, and 1998 (Johnson 1982; Brammer 1990) and damage crops, livestock, life, and property.

However, crop production in Bangladesh mostly depends on groundwater irrigation and the withdrawal of this valuable resource increased due to the shortage of surface water availability and, comparatively easy access to groundwater. Dinajpur is one of the northwestern districts of Bangladesh which is a groundwater governed area for crop production. Previous researches showed a significant declination of the groundwater table by risking sustainability in the study area (Dey et al, 2017; Simonovic, 1997; and Shahid, 2011). Monsoon rainfall can minimize this irrigation requirement and thus the cost by reducing the pressure on the ground and surface water source. Besides, monsoon rainfall's arrival and withdrawal pattern is also a significant deciding factor for copping in this area. The shifting of this season (the arrival and withdrawal dates) can help identify the proper time for planting and harvesting the crop, which may have a great impact on this area's socio-economy. Moreover, our targeted area, Dinajpur, is affected by floods due to heavy rainfall that causes damage to crops and life. That is why identifying the arrival and withdrawal dates of the Dinajpur district's monsoon is now a vital issue these days. If such information is providing to the farmers and the local people, it would help them decide about farm activities and minimize the climatic risk so that the socio-economic condition of this area could be improved. However, no considerable numbers of researches had been carried out yet to analyze the arrival and withdrawal dates of monsoon in Dinajpur district of Bangladesh. That is why this research aimed to identify the arrival and withdrawal dates, observe the trend, assess the shifting, and predict the probabilistic arrival and withdrawal dates of monsoon rainfall in Dinajpur, Bangladesh.

## Materials and Methods

### *Location, geography, and climatic condition of the study area*

The study area, Dinajpur district (Figure 1), is in Bangladesh's northwestern hydrological zone. The study area's location is between 25$^0$10' and 26$^0$04' north latitudes and 88$^0$23' and 89$^o$23' east longitudes. Usually, the climate of Dinajpur District is warm and temperate. The district experiences a wet, hot, and humid tropical climate. According to the Köppen Climate classification, the environment of Dinajpur is humid subtropical. It has a remarkable monsoon period. The annual average temperature is 25$^0$C (77$^o$F). The summer receives more rainfall than the winter, and the average rainfall reported herein is 1728 mm.

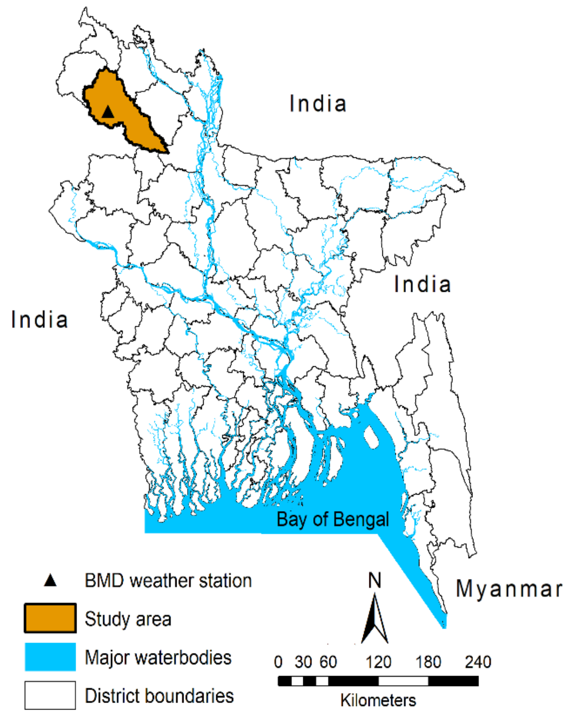


Figure 1: Location of the study area and weather station in the Bangladesh map.

### *Criteria for the determination of arrival dates of monsoon in Dinajpur*

Bangladesh Meteorological Department fixes 1 June as the monsoon arrival date for Bangladesh (Ahasan *et al.,* 2010). However, it is not feasible to clarify the exact date of monsoon arrival date (Das 1986). Ahmed and Karmakar (1993) provided some criteria for identifying the monsoon onset date in Bangladesh. According to their study, two variables- rainfall amount and wind vector- are considered to determine monsoon rainfall's arrival date in Bangladesh. For getting a brief idea of the arrival dates, the daily rainfall (April, May) and wind vector (May) of Dinajpur in 2000 are elucidated in Figure 2. The following criteria are followed to identify the monsoon arrival date of the Dinajpur district from previous studies. the first day of three or more consecutive days having 5 mm or more rainfall along with the southerly or southeasterly winds for the rest of the season.

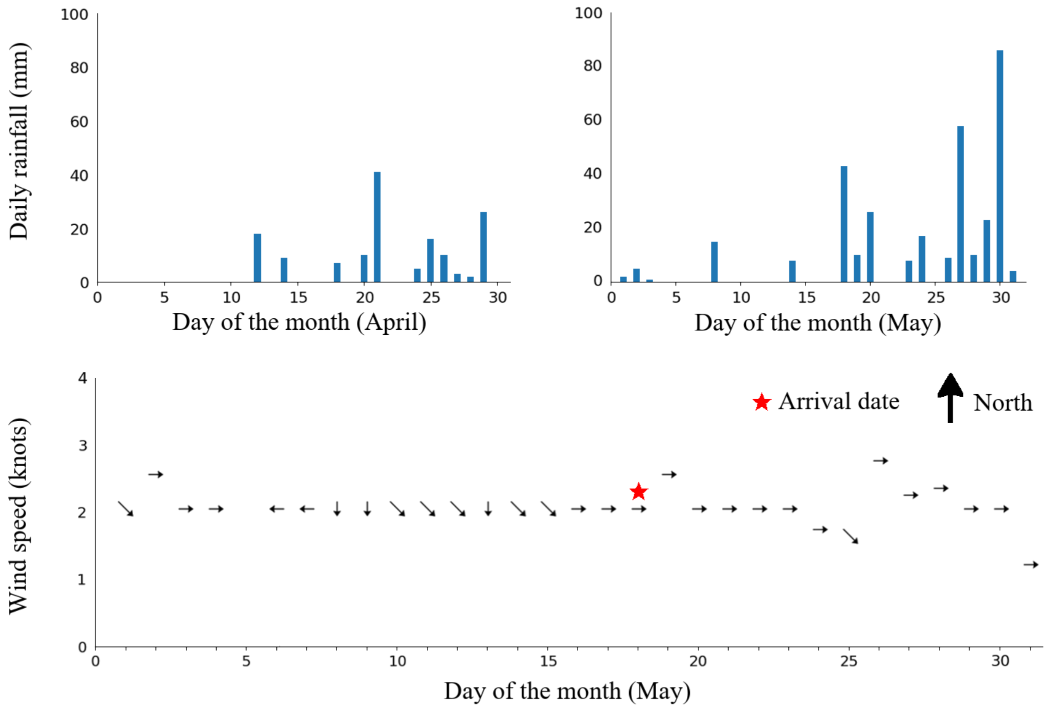


Figure 2. Daily rainfall (April, May) and wind vector (May) of Dinajpur in 2000.

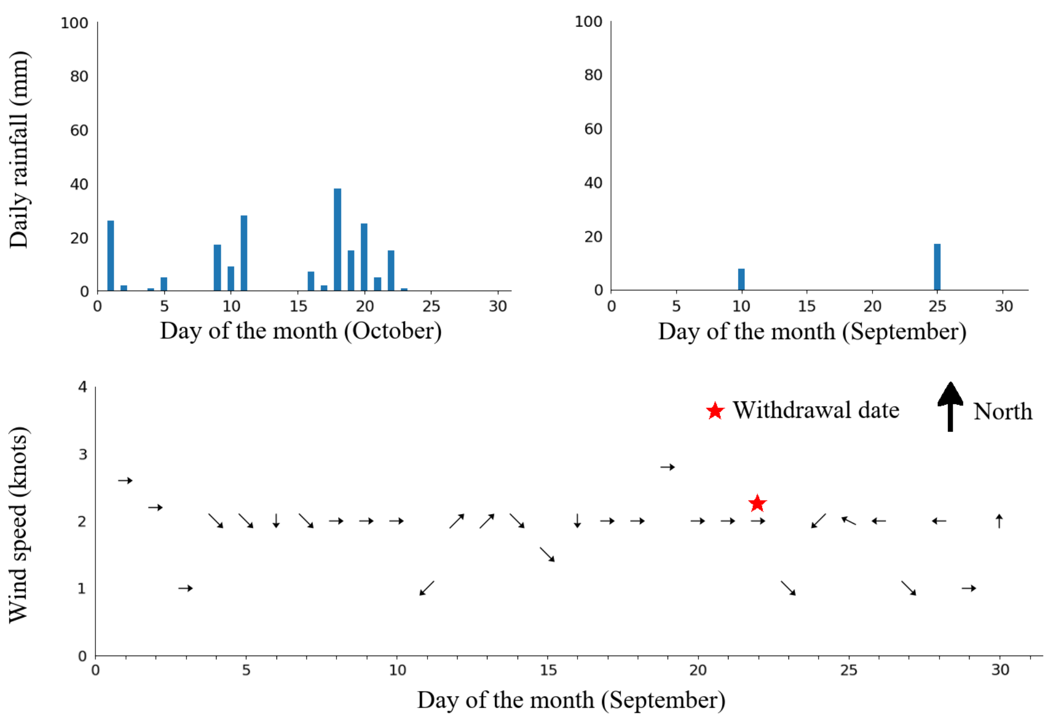


Figure 3: Daily rainfall (September, October) and wind vector (September) of Dinajpur in 2000.

### Criteria for the determination of withdrawal dates of monsoon in Dinajpur

Ahmed and Karmakar (1993) mentioned that the monsoon's withdrawal starts in the reverse direction to the arrival. Moreover, detecting the withdrawal date is more complicated than the arrival date in Bangladesh. However, they provided some criteria for identifying the withdrawal dates of monsoon rainfall. For getting a brief idea of the withdrawal dates, the daily rainfall (September, October) and wind vector (September) of Dinajpur in 2000 are elucidated in Figure 3. The following criteria are followed to identify the monsoon withdrawal date in the Dinajpur district: the last day of three or more consecutive days having 5 mm or more rainfall along with the north-westerly or northerly wind for the rest of the time.

### Data collection and analysis

Daily rainfall (mm) and wind speed (knots) data of 30 years (1986 to 2015) have been collected from Bangladesh Meteorological Department (BMD) station in Dinajpur. Correction for missing data was done in exceptional cases. To determine the arrival and withdrawal dates, the monsoon onsets calculate considering the first date of Julian pentad (Lau and Yang 1997). Thirty numbers of arrival and withdrawal dates were obtained by analyzing the initial data by following the criteria set by Ahmed and Karmakar (1993). In 1987, 2000, and 2003 the arrival dates were obtained before May. In this circumstance, the dates were not considered, though they fulfill the criteria. Only the dates with arrival after 1 May were accepted. The wind directions are considered the standards likewise because it is a natural phenomenon.

The trend of arrival and withdrawal of monsoon rainfall was observed by plotting the data in graphs. Then the shifting of monsoon rainfall has been calculated by considering 1986 as the baseline. Furthermore, in order to perform a detailed probabilistic analysis of monsoon rainfall, the earliest and latest arrival dates for the future of 1 year out of 4, 10, and 25 years were taken into consideration. Such approaches were also applied in the case of probabilistic withdrawal dates. For establishing the probabilistic arrival and withdrawal dates, the data must be distributed normally. The data were tested for normal distribution using Statistical Package for the Social Sciences (SPSS) software. In addition, to estimate the probabilistic arrival and withdrawal dates of monsoon rainfall, the mean rainfall ($X$), standard deviation ($\sigma$), and the number of observation ($n$) dates were computed. By applying the $Z$-score formula, probabilistic dates of arrival and withdrawal of the monsoon of Dinajpur district over expected time-scales obtained. However, to find out the probabilistic arrival and withdrawal dates of the monsoon, the following equation has been used.

$$Xp = X + Z\sigma$$

Here, $Xp$ is the probabilistic estimated date of arrival or withdrawal of monsoon rainfall.

This method is used in this study to obtain the probabilistic dates of the arrival and withdrawal of the monsoon over three different time-scales.

(i) Arrival or withdrawal date in 1 year out of 4 years that gives frequent event. It can be expressed as $Xp = X \pm 0.67\sigma$
(ii) Arrival or withdrawal date in 1 year out of 10 years that gives a less frequent event. It can be expressed as $Xp = X \pm 1.28\sigma$
(iii) Arrival or withdrawal date in 1 year out of 25 years that gives a least frequent event. It can be expressed as $Xp = X \pm 1.75\sigma$

The value of $Z$ is obtained from the $Z$ score percentile table.

In this study, the data were analyzed primarily with Microsoft Excel and IBM SPSS Statistics. In addition, Python modules NumPy (Walt *et al.*, 2011), Pandas (McKinney, 2010), and Matplotlib (Hunter, 2007) along with Excel were applied to visualize the resultant data in this study.

## Results and Discussion

### Arrival and withdrawal dates of monsoon rainfall

The mean arrival and withdrawal dates of monsoon rainfall are 3 June and 27 September respectively in Dinajpur district during 1986-2015. The arrival and withdrawal dates of the monsoon rainfall in the study area are depicted in Table 1. The earliest and latest monsoon arrival dates fluctuated between 4 May and 26 June. It was also apparent that monsoon rainfall withdrawal dates were fluctuating between 30 August and 1 November. The arrival date of monsoon rainfall was the same for the following years 1988 and 1989 (12 May); 1991, 1993 and 1994 (16 May); 1995 and 1997 (17 June); 1987 and 2012 (22 June). Monsoon rainfall's withdrawal date was the same for the following years 1989, 1995, and 2013 (30 September); 1998 and 2005 (22 October). However, Figure 4 demonstrates that the duration of monsoon rainfall followed an identical trend over the target period, including upward and downward fluctuations over the different years. A large-scale variation in summer monsoon rainfall has also been presented by Ahasan *et al.* (2010).

Table1: Arrival and withdrawal dates of monsoon rainfall in Dinajpur from 1986 – 2015.

| Year | Arrival and withdrawal dates of monsoon | | Total duration |
|---|---|---|---|
| | Arrival | Withdrawal | |
| 1986 | 57 | 121 | 64 |
| 1987 | 53 | 116 | 63 |
| 1988 | 12 | 137 | 125 |
| 1989 | 12 | 153 | 141 |
| 1990 | 51 | 168 | 117 |
| 1991 | 16 | 170 | 154 |
| 1992 | 87 | 152 | 65 |
| 1993 | 16 | 167 | 151 |
| 1994 | 16 | 163 | 147 |
| 1995 | 48 | 153 | 105 |
| 1996 | 36 | 152 | 116 |
| 1997 | 48 | 124 | 76 |
| 1998 | 51 | 175 | 124 |
| 1999 | 4 | 174 | 170 |
| 2000 | 18 | 145 | 127 |
| 2001 | 31 | 186 | 155 |
| 2002 | 33 | 149 | 116 |
| 2003 | 54 | 180 | 126 |
| 2004 | 47 | 161 | 114 |
| 2005 | 5 | 175 | 170 |
| 2006 | 28 | 149 | 121 |
| 2007 | 9 | 130 | 121 |
| 2008 | 38 | 122 | 84 |
| 2009 | 25 | 111 | 86 |
| 2010 | 24 | 143 | 119 |
| 2011 | 55 | 142 | 87 |
| 2012 | 53 | 145 | 92 |
| 2013 | 17 | 153 | 136 |
| 2014 | 27 | 146 | 119 |
| 2015 | 56 | 128 | 72 |
| x | 34.23 | 149.67 | |
| n | 30 | 30 | |
| $\sigma$ | 20.06 | 19.97 | |

**1 means the 1st day of May. As like this, 57 means 26 June (e.g. 121 means 29 September of that particular year).

### *Trend of arrival and withdrawal dates of monsoon rainfall*

In 1987, 1988, 1991, 1993, 1996, 1999, 2004, 2005, 2007, 2009, 2010, 2012 and 2013, the arrival dates of monsoon go downward (Figure 5). It indicates that the monsoon came early in the following years than in their previous year. Rest of the years, the arrival date of monsoon rainfall came relatively late than the previous year. Overall, it is seen that the arrival pattern of monsoon is not the same for all the years. In 1987, 1992, 1994, 1995, 1996, 1997, 1999, 2000, 2002, 2004, 2006, 2007, 2008, 2009, 2011, 2014 and 2015 the withdrawal dates go downward (Figure 5). It means that in those years, the withdrawal date came earlier than the previous one. Rest of the years, the withdrawal of monsoon came relatively late for each year than the previous one. The arrival and withdrawal dates were fluctuating between May to June and August to November, respectively. However, it has been noticed that most of the arrival and withdrawal dates were within the standard range (June to September).

### *Shifting of arrival and withdrawal dates of monsoon rainfall*

The early and late arrival and withdrawal shifting days of monsoon rainfall from 1986 – 2015 are depicted in Figure 6. In 1992, the arrival dates of monsoon rainfall shifted 30 days later than the year 1986. Except this, the dates turned earlier (considering arrival date of 1986 as baseline) in the other years. The range of the early arrival dates lies between 1 – 53 days, while the late withdrawal shifting varies between 1 – 69 days.

For most of the years, the monsoon rainfall period was lengthier than the base period (1986) as the arrival dates are coming earlier and the withdrawal dates are delaying.

### *Total and mean monsoon rainfall*

The total and mean monsoon rainfall in the study area from 1986 to 2015 is shown in Figure 7. Total monsoon rainfall was observed to have followed a minor downward trend over the targeted period but it is not significant. Furthermore, it was revealed that the total amount of rainfall (2782 mm) was highest in 2005 and the lowest amount of (757 mm) was obtained in 1992. In 1994, mean rainfall (7.03 mm/day) was the smallest, while the largest mean rainfall (44.11 mm/day) in 1987.

Previous researches showed a significant increase in annual monsoon rainfall for the Northern part of Bangladesh where the study area is situated. On the contrary, a decreasing trend (-9.1 mm/yr) in monsoon rainfall has also been observed in the North-Eastern region of Bangladesh. The fluctuations in monsoon rainfall may occur due to the movement of the monsoon trough in the north-southerly direction (Shahid & Osman, 2009 and Ahasan *et al.*, 2010).

### *Test for normal distribution*

The statistical normality test of arrival and withdrawal dates of monsoon rainfall was performed using SPSS (Table 2). In this table, the values are more significant than 0.05. So, the arrival and withdrawal data of monsoon rainfall are normally distributed.

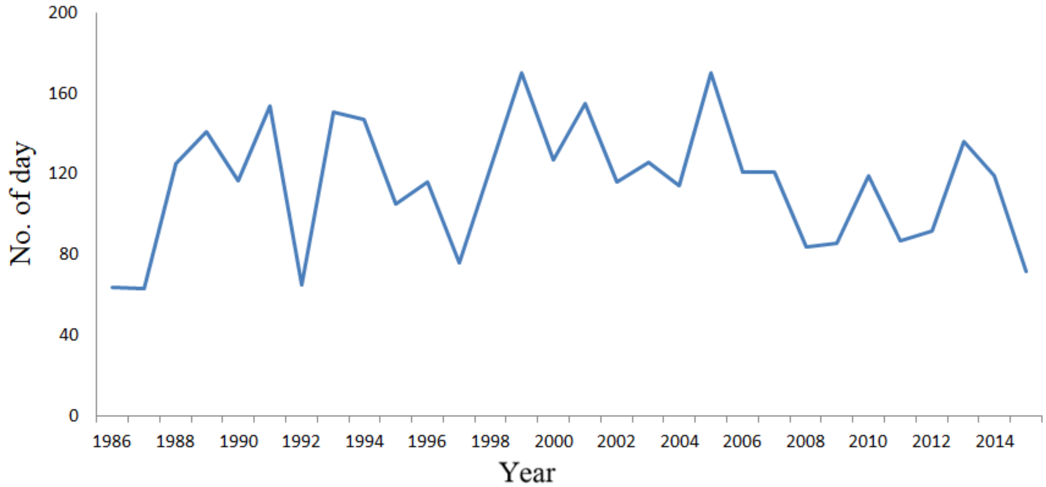


Figure 4. Duration of monsoon rainfall during the year 1986- 2015 in Dinajpur, Bangladesh.

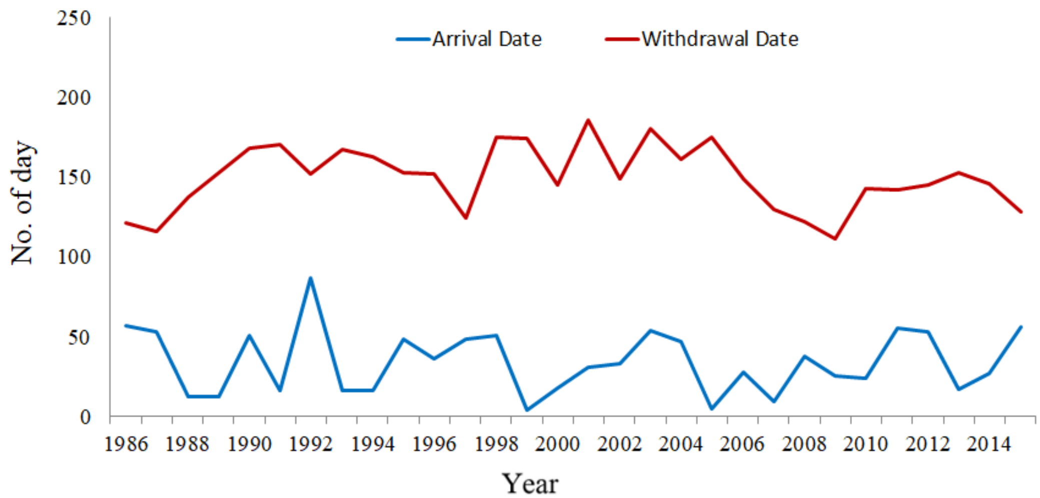


Figure 5. Arrival and withdrawal trend of monsoon rainfall during 1986- 2015 in Dinajpur, Bangladesh.

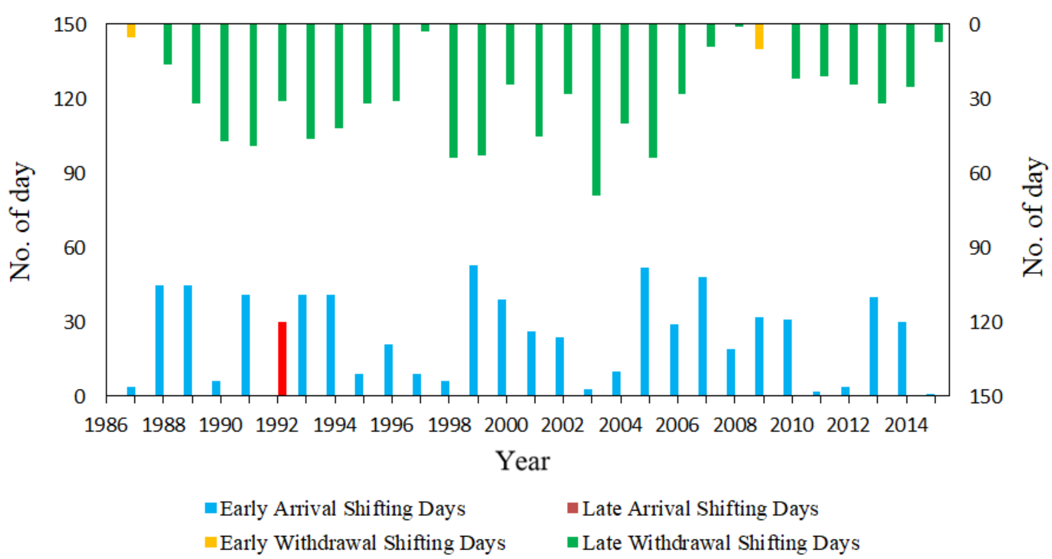


Figure 6. Early and late arrival and withdrawal shifting days of monsoon rainfall from 1986 to 2015.

*Probabilistic arrival and withdrawal dates of monsoon rainfall:*

Probabilistic early and late dates of arrival and withdrawal of the summer monsoon have been calculated and analyzed to observe the occurrence of frequent, less frequent, and least frequent monsoon rainfall events in the study area where these three events are characterized by 1 out of 4 years, 1 out of 10 years, and 1 out of 25 years, respectively. The probabilistic dates of monsoon rainfall of Dinajpur District for the three defined time-scales are presented in Table 3. The investigation has shown that 21 May, 9 May, and 30 April are the earliest monsoon rainfall arrival dates for future 1 year out of 4 years, 10 years, and 25 years, respectively. The result also presented that 17 June, 29 June, and 8 July are the latest monsoon rainfall arrival dates for the same years. A little variation in early arrival dates 9 June, 4 June, and 1 June and almost similar late arrival date 21 June, 27 June, and 1 July in future 1 year out of 4 years, 10 years, and 25 years, respectively for the North-Western part of Bangladesh were observed from the research of Ahmed and Karmakar (1993). In addition, the earliest withdrawal dates of monsoon rainfall have been observed 13 September, 1 September, and 23 August for 1 year out of 4 years, 10 years, and 25 years. The latest withdrawal dates are 10 October, 22 October, and 1 November for the same years. Ahmed and Karmakar (1993) reported the beginning of the early withdrawal of the summer monsoon rainfall in the North-Western part of Bangladesh by 24 September, 19 September for 1 out of 4 years and 10 years, respectively, and 15 September for 1 out of 25 years (extreme event) in the West-Central part of the country. The distributions of the beginning of the late dates of withdrawal of the summer monsoon in the North-Western part of Bangladesh were also reported by 5 October and 11 October in 1 out of 4 and 10 years, respectively, and 14 October for the extreme event 1 out of 25 years in the West-Central part of the. The research of Ahmed and Karmakar (1993) suggested a similar pattern of the early and late withdrawal dates with the findings for 1 out of 4 and 25 years. Besides, it was saliently demonstrated from the current study that the arrival dates are coming earlier from the probabilistic dates, and the withdrawal dates are completing later with the increase of the future years. Consequently, the monsoon period is relatively becoming longer than in the past historical years.

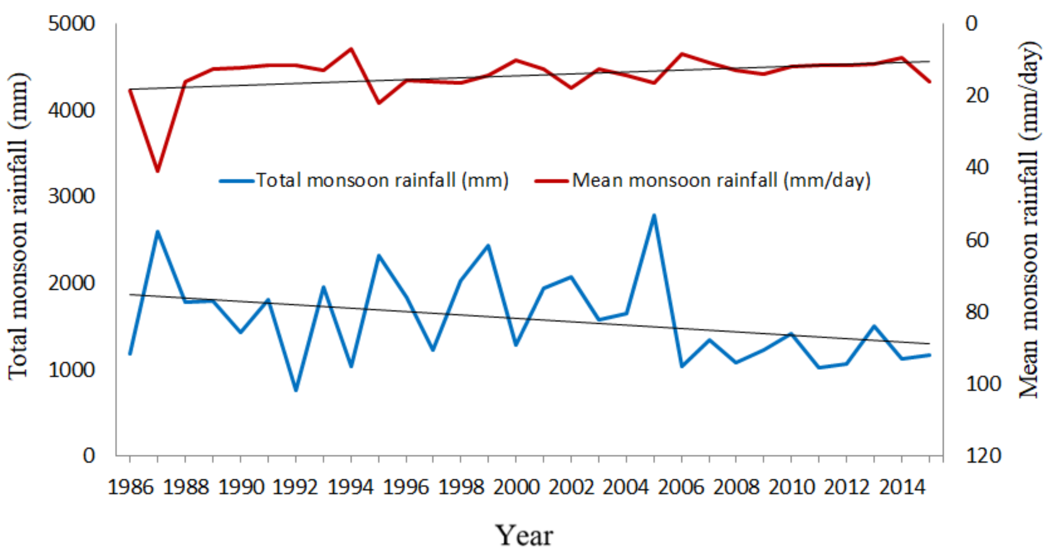


Figure 7. Total and mean monsoon rainfall from 1986 – 2015.

Table 2: Statistical normality test of arrival and withdrawal dates of monsoon rainfall by using SPSS

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| Arrival | 0.138 | 30 | 0.152 | 0.937 | 30 | 0.074 |
| Withdrawal | 0.100 | 30 | 0.200* | 0.972 | 30 | 0.596 |

*Lower bound of the true significance; [a]Lilliefors Significance Correction

Table 3: Probabilistic arrival and withdrawal dates for three defined time-scales

| Return period | Probabilistic dates | | | |
|---|---|---|---|---|
| | Earliest arrival | Latest arrival | Earliest withdrawal | Latest withdrawal |
| 4 years | 21 May | 17 June | 13 September | 10 October |
| 10 years | 9 May | 29 June | 1 September | 22 October |
| 25 years | 30 April | 8 July | 23 August | 1 November |

## Conclusion

This study demonstrated that the mean arrival and withdrawal dates for monsoon rainfall were 3 June and 27 September, respectively, in the Dinajpur district during 1986- 2015. The dates of arrival and withdrawal fluctuated between May to June and August to November, respectively. However, it was noted that most of the arrival and withdrawal dates were within the standard range (June to September). In addition, early arrival dates ranged from 1 to 53 days, except in 1992 (30 days later than 1986). In the case of withdrawal dates, the late withdrawal dates were between 1 – 69 days, except in 1987 and 2009 (5 days and 10 days earlier than 1986). Thus, the overall monsoon period was found to be longer than in previous years. It was moreover revealed that the total rainfall in the monsoon period was reported to have followed a marginal downward trend over the targeted duration. Besides, the arrival dates were earlier than the probabilistic dates, while the withdrawal dates were completed later in the years; therefore, the monsoon period is becoming prolonged than in the past historical years. Overall, it can be inferred that the findings of the study would be useful, particularly for agricultural purposes, by understanding the shifting and probabilistic patterns of the arrival and withdrawal dates of monsoon rainfall in a particular region. However, further research following such approaches in other regions of Bangladesh is also recommended, which will help to draw a better conclusion on the appraisal of the arrival and withdrawal dates of monsoon rainfall.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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