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Six or four seasons? An evidence for seasonal change in Bangladesh

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Six or four seasons? An evidence for seasonal change in Bangladesh

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Abstract

Bangladesh is reported to suffer from climatic changes, and many local people begin to wonder that six seasons in Bangladeshi annual calendar transition to four seasons where the traditional one (Bangla calendar) is considered to have consisted of the six seasons. We collected observations of key climate variables (1953-2010) from the weather station located in Dhaka, and conducted face-to-face surveys with 1,011 respondents and seven experts to elicit their current perception about whether six seasons are becoming four seasons. To scientifically confirm this, we apply nonparametric statistical methods to the key climate variables and test whether any pair of two neighboring seasons in Bangla calendar is converging into one. The statistical analysis shows "convergence" for specific two pairs of two neighboring seasons, meaning that the annual calendar now consists of four seasons, not six. Approximately 65% of respondents believe that annual calendar transitions to four seasons from six seasons. Overall, people's perception and the statistical analysis are consistent each other. The effect of global climatic changes now becomes significant to the extent that local people correctly perceive some fundamental seasonal changes of annual calendar and it is really ongoing on the basis of our statistical analysis.

Key Words: Climatic change; seasonal change; perception

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1 Introduction

Bangladesh is one of the most disaster-prone countries in the world because of its geographical setting (Brouwer et al., 2007). Bangladesh is part of the Bengal Basin, one of the largest geo-synclinal countries in the world. It lies in the northeastern part of South Asia, between latitudes 20° $34'N$ and 26° $38'N$ and longitudes 88° $01'E$ and 92° $41'E$ and has a gross area of approximately 147,570 km^2. Approximately 80% of the country's land is the floodplains of three large rivers, the Ganges, the Brahmaputra and the Meghna. Only 10% of Bangladesh is 1 m above the mean sea level (MSL) and one-third is under tidal influence.

Bangladesh is likely to be affected by more intense and frequent flood events in the foreseeable future due to potential climate changes and the associated MSL rise (Schiermeier, 2011a,b). This is an issue of great concern, because the location and geography of Bangladesh makes it both particularly susceptible to such effects of climatic changes on agriculture and other industries, and extremely difficult to protect. To make matters worse, many Bangladeshi people gradually recognize some potential change of seasons in annual calendar. That is, annual calendar in Bangladesh transitions from six seasons to four seasons. Despite the importance of this fundamental climate issue, no studies have examined the possible seasonal change and the corresponding people's perceptions in relation to historical climate data. Thus, this paper seeks to address these issues.

We conducted a questionnaire survey of 1,011 respondents and seven experts to elicit their perceptions about whether Bangladeshi annual calendar consists of four or six seasons, and obtained corresponding climate data from three meteorological stations located in the same area. Using the climate data, we apply nonparametric statistical tests to scientifically identify whether any pair of two neighboring seasons in Bangla calendar is converging into one seasons, and compare the statistical result with people's perceptions. With this approach, our research addresses a following question: "Is Bangladesh subject to four seasons or six seasons in an annual calendar, and what are people's perceptions of this possible seasonal change?"

2 Study area and data collection

2.1 Study area

The Meghna Basin area of Bangladesh was selected as a study area because it is vulnerable to climatic changes and frequent flooding. Within the Meghna Basin area in central Bangladesh, the administrative Upazilas—Narsingdi Sadar and Raipura were chosen. The two Upazilas are characterized by different production potentials. Figure 1 is a map of the research area. Raipura has relatively higher agricultural potential, whereas Narsingdi Sadar has lower agricultural but higher industrial potential. The household is a unit of analysis, because it is the decision-making unit in livelihood processes, with the senior and earning male person household member as the decision maker. The survey was conducted in 2011 and 2012. The climatic conditions in Raipura and Narsingdi Sadar have relatively uniform temperatures, high humidity, and heavy rainfall. Heavy rain usually occurs from June to September. The average annual temperature ranges from $13°\mathrm{C}$ to $35°\mathrm{C}$. The rivers in the Upazilas are Meghna (the most important), Old Brahmaputra, Arial Khan and Kakan. Because Raipura Upazila and Narsingdi Sadar Upazila are plain lands, the Meghna floods, especially in the rainy seasons.

[Figure 1 about here.]

2.2 Meteorological data

Daily weather data were collected from the Bangladesh Meteorological Department. The data includes daily rainfall, daily average temperature, daily maximum temperature and daily minimum temperature. To identify a change from six to four seasons in the annual calendar, we analyzed Dhaka station's data from the last 57 years because only this station has data covering more than 50 years in Bangladesh and because it is closest to the study area (38.4 km). Finally, figure 2 summarizes the data collection procedure consisting of a primary field survey, a household survey, an expert interview and the collection of meteorological data.

[Figure 2 about here.]

3 Methodology and data analysis

3.1 Seasonal change from six to four seasons

The usage and popularity of the Bangla calendar in Bangladesh are partly due to its adaptation to the unique seasonal patterns of the region. Bangladesh has a climate that has been considered to be divided into six seasons, including the rainy season and the dry season in addition to spring, summer, fall and winter. In our survey, a large share of respondents think that the timing of seasonal changes has become unpredictable. In addition, local people and experts wonder that the six-season country is losing its seasonal variation and is changing to a land of four seasons or less, although no previous works present supporting evidence for this. Table 1 presents the Bangla local calendar. We use this calendar to test whether people's perceptions of seasonal changes are in line with actual climate data obtained from the Bangladesh Meteorological Department. More specifically, our analysis was conducted by utilizing the climate data taken from the Dhaka meteorological station and analyzing four key climate variables: average daily maximum temperature, average daily minimum temperature, average daily mean temperature and average daily rainfall.

[Table 1 about here.]

We analyzed all possible pairs of two consecutive seasons in the Bangla calendar to identify whether the two seasons are merging into a single season. First, we began with a simple graphical analysis to observe the temporal trend of climate variables over the years of 1953 to 2010 in each season. Next, we applied non-parametric Mann-Whitney tests by dividing the sample of a climate variable in each season into two subsamples. Each subsample represents data from 1953 to 1984 as a "old period" subsample of the season or data from 1985 to 2010 as the "recent period" subsample. Note that this separation was determined by the experts' opinions in the survey.

Mann-Whitney tests can be used to compare the subsamples of a climate variable in the same period (old or recent period). The hypotheses can be posed as follows:

- H_0: The two "old" ("recent") subsamples of a climate variable over the two consecutive seasons follow an identical distribution.
- H_A: The two "old" ("recent") subsamples of a climate variable over the two consecutive seasons follow different distributions.

Utilizing old and recent subsamples of a climate variable, i.e., average temperature, in the two consecutive seasons, the Mann-Whitney test should be able to statistically conclude whether a pair of two neighboring seasons within the six-season calendar are converging. More concretely, when two consecutive seasons do not merge, the Mann-Whitney test should reject the null hypothesis for both old and recent subsamples of the climate variable over the two seasons. For instance, the two old subsamples of average daily temperatures over the summer and rainy seasons should reject the null hypothesis, so do the two recent subsamples over the summer and rainy seasons.

When two seasons are converging, the null hypothesis should be rejected for the old subsamples, but not for the recent subsamples. This means that Bangladesh was subject to six seasons within a year, implying that the null hypothesis must be rejected using old subsamples. At the same time, if our "merging" or "four-season calendar" hypothesis is true, the null hypothesis should not be rejected using recent subsamples, implying that the recent subsamples of climate data over the two seasons do not differ. For example, the two old subsamples of rainfall over the summer and rainy seasons should reject the null, but the two recent subsamples of the rainfall over the summer and rainy seasons should not reject the null. In that case, we interpret that these two seasons were different, but they have been converging in the recent years.

4 Results and discussion

4.1 Seasonal change from six to four seasons

This study examines whether six seasons become four seasons in the Bangla annual calendar. To test this hypothesis, we analyzed all possible pairs of neighboring seasons to identify whether a climate variable in the two neighboring seasons is becoming indistinguishable or at least less distinguishable over time. The set of key variables in the analysis of seasonal changes consists of temperature and rainfall in Dhaka where the richest climate data are available. In the following subsection, we present the two pairs of consecutive seasons that support our "merging" hypothesis. Note that analysis of the other pairs rejected the "merging" hypothesis, and thus we omit the presentation of the "rejected" results.

4.1.1 Rainy season vs. pre-autumn season

The rainy and pre-autumn seasons are consecutive Bengali seasons that have been considered distinct and that have been believed to have significant, but different impacts on agriculture and daily life (table 1). This conclusion had been supported by individual experiences and meteorological data. However, we hypothesize that in recent years, these seasons have been becoming indistinguishable or more similar each other.

[Figure 3 about here.]

To analyze whether the two seasons are becoming more similar, we focus on average daily minimum, maximum and mean temperatures and rainfall for the rainy and pre-autumn seasons (figure 3). Climate variability in these two seasons has significance for domestic crops and everyday life. Subfigures 3(a), 3(b) and 3(c) are the time series plots of the average daily minimum, maximum and mean temperatures for the rainy and pre-autumn seasons from 1953 to 2010, respectively. They show an increasing temporal trend, and the coefficients of the trend lines in each subfigure are greater for pre-autumn season than for the rainy season. The pre-autumn temperatures were lower than those in the rainy season, but the two seasons are converging over time. The trend lines for the pre-autumn season cross those in the rainy season in all three subfigures 3(a), 3(b) and 3(c).

Regarding rainfall, figure 3(d) plots the daily average rainfalls in the rainy and autumn seasons from 1953 to 2010. This figure shows that the temporal trend in the rainy season is constant, whereas it is increasing in the pre-autumn season. Consequently, the trend lines for the two seasons cross (see figure 3(d)). The single crossover suggests that the daily average rainfalls in the rainy and pre-autumn seasons are converging. The Mann-Whitney tests for the rainy $vs.$ pre-autumn seasons examine the null hypothesis of "merging" that the two subsamples (the rainy $vs.$ pre-autumn seasons) from the old period (1953-1984) follow an identical distribution (or the same data generating process) for each climate variable. The same test is applied using the two subsamples (the rainy $vs.$ pre-autumn seasons) from the recent period (1985-2010), too. Table 2(a) summarizes the test results and suggests that climate variables in the rainy and pre-autumn seasons differ in old subsamples, but do not differ in recent subsamples, supporting our hypothesis that the rainy and pre-autumn seasons are converging.

[Table 2 about here.]

4.1.2 Summer season vs. rainy season

The summer and rainy seasosn are consecutive Bengali seasons that have been considered distinct (table 1). These two seasons are hypothesized to be converging based on the opinions of experts and local people. Following the same procedure before, we analyze each climate variable for the two seasons. Figure 4 consists of four subfigures with time-series plots of climate variables for the two seasons. Each subfigure shows that climate variables of the two seasons are becoming closer over time. In particular, subfigures 4(a), 4(c) and 4(d) are consistent with this trend for the minimum, mean temperature and rainfall, respectively. The two trend lines (summer $vs.$ rainy) for each climate variable cross except the maximum temperature of subfigure 4(b). In general, however, the two trend lines for the rainy and summer seasons can be said to become closer over time.

[Figure 4 about here.]

Based on the observations summarized in figure 4, it is likely that the rainy and summer seasons are converging. To confirm this observation, we ran Mann-Whitney tests for the four climate variables. Subtable 2(b) presents the result, suggesting that for old subsamples, minimum temperature, maximum temperature and rainfall differ, while mean temperature does not. For recent subsamples, only maximum temperature significantly differ between the two seasons, while minimum, mean temperatures and rainfall do not differ. In summary, this result supports our hypothesis that the rainy and summer seasons are converging; three climate variables are different in old subsamples, but the only one climate variable is different in recent subsamples.

The results presented in this subsection for this seasonal change is quite consistent with the perceptions of local people. According to the household survey from the study area, 660 respondents (660/1,011, 65%) perceived the change from six to four seasons. In contrast, 351 respondents did not perceive any such change. Furthermore, seven experts asserted that this change is occurring. Overall, the statistical analysis, people's perceptions and experts' opinions are consistent in this regard.

5 Conclusion

This paper examined whether annual Bangladeshi calendar transitions to four seasons from six seasons by looking at the basic daily climate variables of temperature and rainfall. Surprisingly, we find that two pairs of two consecutive seasons in Bangla calendar are merging or at least indistinguishable for the recent periods. This evidence for the seasonal change must be seriously taken, because they fundamentally affect agriculture and daily life of Bangladeshi people where the current practices of economic production activities have been adapted to six season assumptions. We believe that no previous papers identify an evidence for the seasonal change in a single country and this Bangladeshi evidence shall be a starting point to examine whether any other possible seasonal change may occur in other parts of the world. We would like to note that climatic changes now become significant to the extent that local people realize the seasonal change, consistently with the time series climate data.

6 Bibliography

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Figure 1: A map of the study area. The left map depicts the positions of 34 ground-base weather stations located in Bangladesh with each station marked by a circle on the map. The right map shows the position of Narsingdi Sadar and Raipura Upazilas in Narsingdi District, where we conducted surveys

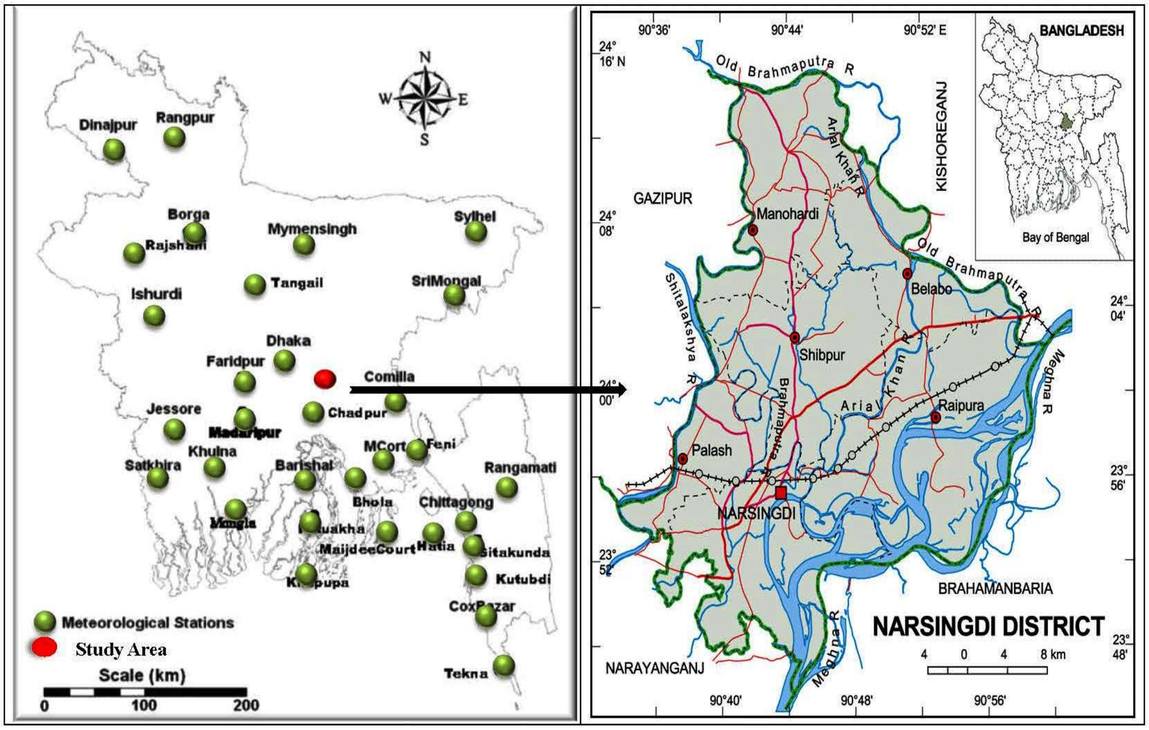
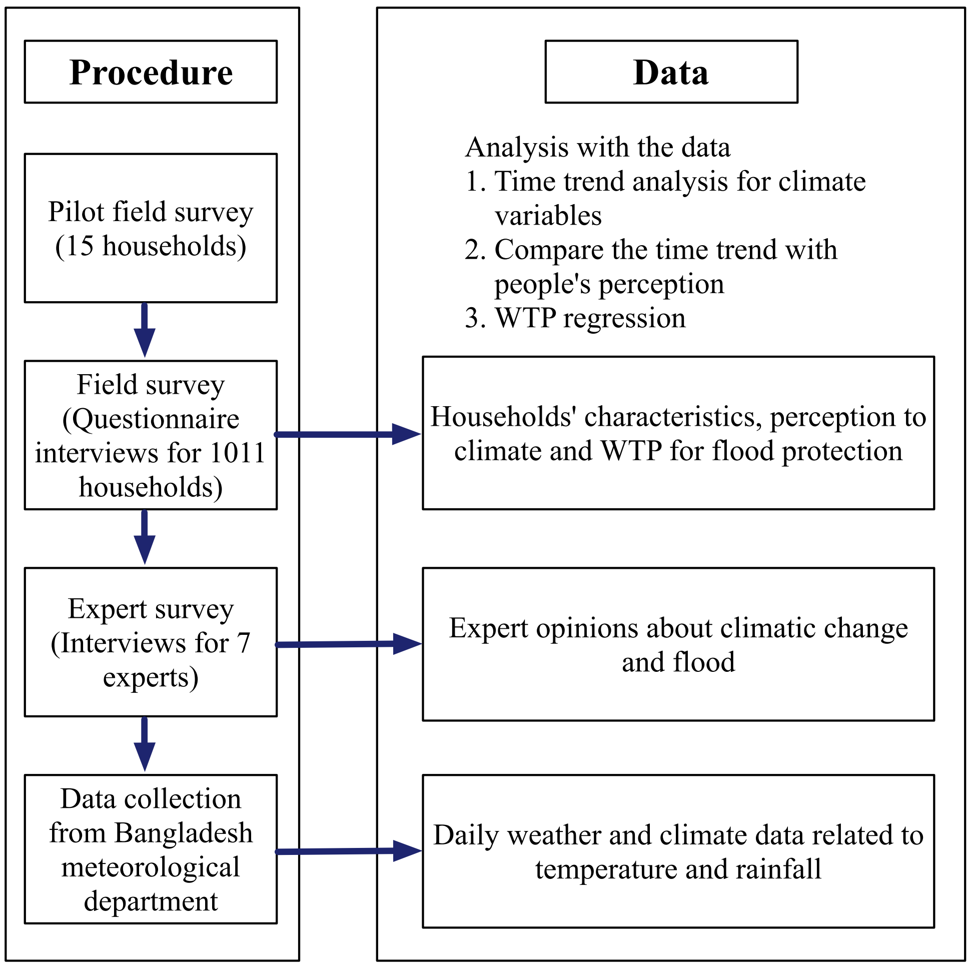
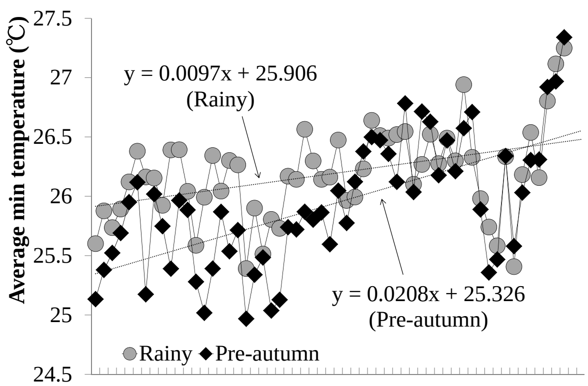
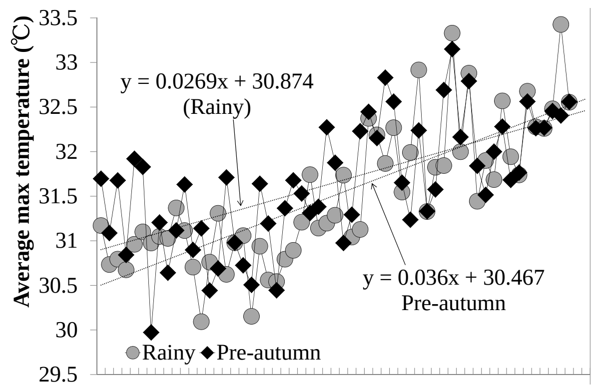


Figure 2: The entire procedure of data collection

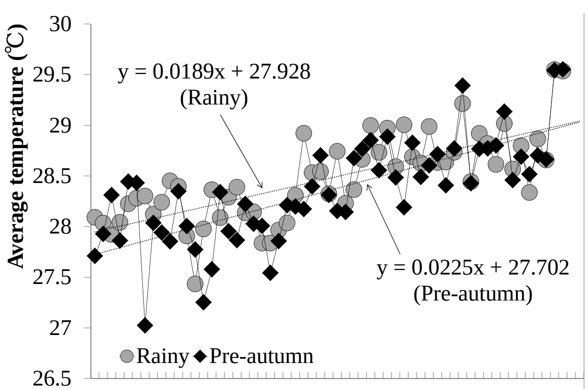




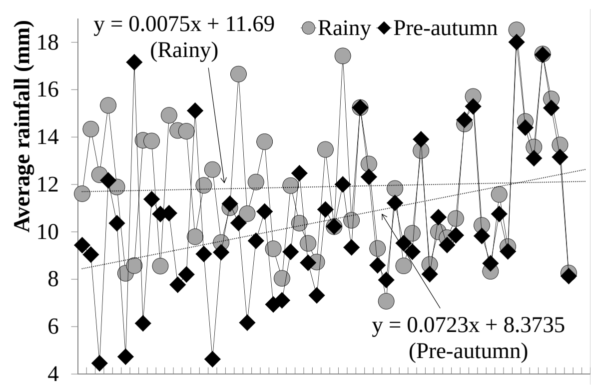
(a) Average daily minimum temperature in the rainy and pre-autumn seasons from 1953 to 2010



(b) Average daily maximum temperature in the rainy and pre-autumn seasons from 1953 to 2010

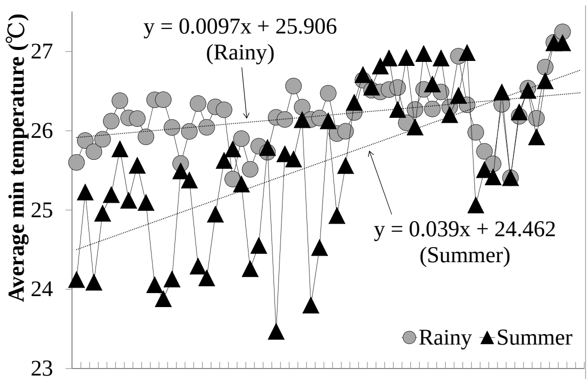


(c) Average daily mean temperature in the rainy and pre-autumn seasons from 1953 to 2010

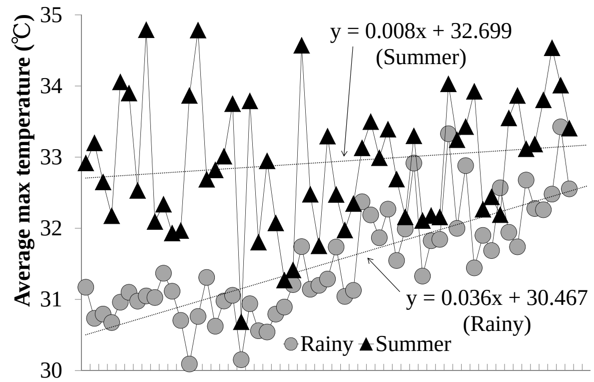


(d) Average daily rainfall in the rainy and pre-autumn seasons from 1953 to 2010

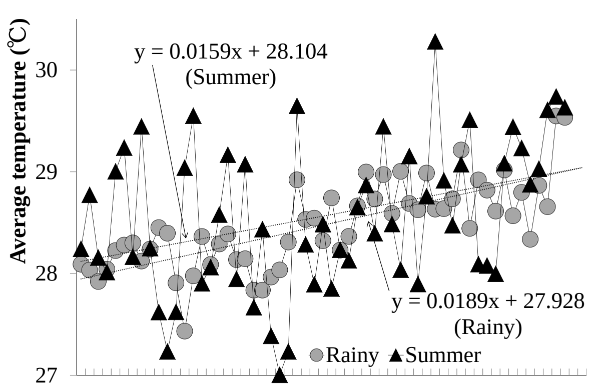
Figure 3: Rainy season vs. pre-autumn season with respect to average daily maximum, minimum and mean temperatures and average daily rainfall



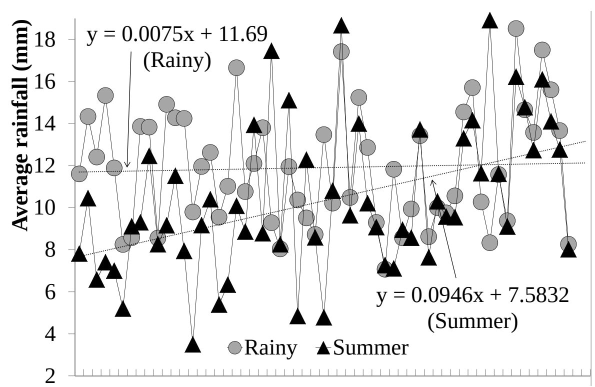
(a) Average daily minimum temperature in rainy and summer seasons from 1953 to 2010



(b) Average daily maximum temperature in rainy and summer seasons from 1953 to 2010



(c) Average daily mean temperature in rainy and summer seasons from 1953 to 2010



(d) Average daily rainfall in rainy and summer seasons from 1953 to 2010

Figure 4: Rainy season vs. summer season with respect to average daily maximum, minimum and mean temperatures and average daily rainfall

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Table 1: Bangla calendar

Bangla season	Bangla calendar	Gregorian calendar	Days
Summer	Baishakh	14 April - 14 May	31
	Jaishtha	15 May - 14 June	31
Rainy season	Ashar	15 June - 15 July	31
	Shraban	16 July - 15 August	31
Pre-autumn	Bhadra	16 August - 15 September	31
	Ashwin	16 September - 15 October	30
Late-autumn	Karttik	16 October - 14 November	30
	Agrahayan	15 November -14 December	30
Winter	Paush	15 December - 13 January	30
	Magh	14 January - 12 February	30
Spring	Falgun	13 February - 13 March	30*
	Chaitra	14 March - 13 April	30

$*$ It becomes 31 in leap year.

Table 2: Mann-Whitney test to compare the two seasons for each climate variable in both old and recent periods

(a) Rainy season vs. Pre-autumn season

Subsample	Min temp	Max temp	Mean temp	Rainfall
Old	4.726^{***}	2.256^{**}	1.772^{*}	3.223^{*}
Recent	0.126	0.34	0.31	0.941

(b) Rainy season vs. Summer season

Subsample	Min temp	Max temp	Mean temp	Rainfall
Old	5.948^{***}	-6.432^{**}	-0.121	3.357^{*}
Recent	-0.708	-4.104^{***}	-0.805	0.437

Note: $*$Significant at the 10% level, $**$Significant at the 5% level, $***$Significant at the 1% level.