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Analysis of rainfall pattern in Dhaka city using linear regression

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Abstract

This study examined the recent rainfall trend in Dhaka city (1996–2021) in this study. MS-Excel was utilized to complete the necessary computation and charting, and the simple linear regression method was employed as the statistical technique. The outcome demonstrates that the trend of rainfall is declining. The average annual rainfall is declining at a rate of 0.0366 millimeters per year. While yearly total winter rainfall is increasing at a pace of 1.6096 mm/year, total pre-monsoon rainfall is declining at a rate of 5.0031 mm/year, annual total monsoon rainfall is falling at a rate of 7.8868 mm/year, and total post-monsoon rainfall is decreasing at a rate of 2.1453 mm/year. However, the annual total winter rainfall is increasing at a rate of 1.6096 mm/year. Every variation in the rainfall pattern has a major impact on Dhaka's climate and weather. It has now grown to be one of the biggest environmental issues. These rainfall pattern tendencies indicate that the future climate will vary, resulting in a varied weather pattern across the city's seasons.

Keywords: Meteorology, trend analysis, regression analysis

Introduction

The climate of Bangladesh, which lies in the tropical monsoon zone is defined by temperature, relative humidity, rainfall, and dew temperature, with some noticeable seasonal fluctuations. The primary natural factor influencing Bangladesh's agricultural output is rainfall. An important aspect of agriculture and our nation's economy is the fluctuation of rainfall and the trend of abnormally high or low precipitation (Karl *et al.* 2008). Rainfall patterns are altering globally and regionally. As a result, of global warming, as is widely known. The main physical mechanism connecting weather, climate, and hydrological cycles is rainfall, which returns water from the atmosphere to the Earth's surface (Solomon *et al.* 2007). Bangladesh's rainfall-dominated climate receives the world's most intense rainfall. The monthly, seasonal, and yearly rainfall in Bangladesh did not show any discernible trends. The main rainy seasons in Bangladesh are the summer and monsoon, which together provide around 84% of the country's yearly precipitation. The most pressing issue of recent time is climate change. Due to global warming, the climate is changing daily on both a regional and global scale (Karl *et al* 2008). In many parts of the world, especially Bangladesh, where hydrological disasters are frequent, the effects of climate change are profound. Bangladesh is one of the most negatively impacted nations by climate change. However, the study reveals that the monsoon season accounts for almost 57% of rainfall. Finding patterns in long-term hydrological data sets is extremely important from a scientific and practical standpoint. The quality of the datasets—most importantly, their homogeneity—also affects the outcomes of climate analyses (Chen *et al.* 2011). The magnitude of the anticipated changes makes it appear foolish to rely solely on antiquated methods of extreme estimation. According to estimates, climate change will cause temperatures to rise significantly and alter rainfall patterns, which will undoubtedly have an impact on both public health and our agricultural industries (Samad *et al.* 2017). The climate of Bangladesh, which is in the tropical monsoon zone is typified by high temperatures, a lot of rainfall, a lot of humidity, and very noticeable seasonal fluctuations (Monirul *et al.*). Bangladesh's capital is Dhaka. It is located at the nation's center. The weather in Dhaka has a significant effect on the entire nation (Banglpedia 2014). The climate has been quickly changing over the past few

decades for a variety of causes (IPCC. Climate Change, 2007). This study employed simple regression analysis to create a graph of the relatable data for the last 26 years (1996–2021) in the Dhaka region in order to determine trends in the annual mean pre-monsoon rainfall, annual mean monsoon rainfall, and annual mean post-monsoon rainfall.

Methodology

Regression analysis: A set of statistical methods, which are used for the estimation of relationships between a dependent variable and one or more independent variables is called regression analysis. In this study, we have used simple linear regression to approximate equation of the trend. The linear regression equation has the following form: $Y = \alpha x + \beta$

with $\propto = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sum_{i=1}^{n}(x_i - \overline{x})^2}$

$$\beta = \overline{y} - \propto \overline{x}$$

where is the slope of the trendline and βis the intercept of this line with y axis. x_i and y_i are the independent and dependent variables respectively and is the average of the dependent variable and is the mean value of the independent variables.

Coefficient of determination (R^2): R-squared is a statistic which provides a measure of how well observed outcomes have been replicated by the model. The formula to compute this statistic is:

$$R^2 = 1 - \frac{SSres}{SStotal}$$

Here, is the residual sum of squares and is the total sum of squares which are calculated by:

$$SSres = \sum_{i=1}^{n}(y_i - f_i)^2 = \sum_{i=1}^{n}(e_i)^2$$

$$SStotal = \sum_{i=1}^{n}(y_i - \overline{y})^2$$

The value of r-squared normally varies from 0 to 1. If the regression line fits the data set properly then the value of r-squared will be closer to 1 (https://corporatefinanceinstitute.com/resources/knowledge/other/rsquared/.)

Results and discussion

In this study we have divided the whole year into four different categories for better analysis of rainfall. The year has been divided into four categories according to different seasonal rainfall (https://www.bmd.gov.bd). They are-

- **The Summer**: The summer season is considered from March to May. It is also called the pre-monsoon season of rainfall.
- **The Monsoon:** The monsoon is considered from June to September
- **The Post Monsoon:** The post-monsoon is considered from October to December.
- **The Winter:** The winter is considered from January to February.

The annual maximum, minimum and mean rainfall of Dhaka city has been determined using the historic available data provided by Bangladesh Meteorological Department (BMD). To analyze the recent trend of rainfall we have used linear regression with yearly average, maximum and minimum rainfall. To determine the rate of change of trend we have used linear regression. We have also computed the R-Squared statistic to determine how good the trend line fits the data points. For seasonal analysis we have also used linear regression and R-Squared statistic.

We found that the highest annual total pre-monsoon rainfall was 969 mm in 2000, while the lowest total rainfall was 225 mm in 2009. The trend of the average annual rainfall has been examined in this study. Over the specified period, the annual average rainfall trend is declining over the examined area; this is a negative trend that is statistically significant with an R-Squared value of 0.0564. Figure 1 illustrates the 5.0031 mm/year decline in the yearly total pre-monsoon rainfall. There has been a notable shift in the city's pre-monsoon rainfall (Ahmed 1989).

According to the study, 2007 saw the highest annual total monsoon rainfall of 2065 mm, while 2012 saw the lowest total rainfall of 764 mm. The trend of the annual total monsoon rainfall has been examined in this study. With an R-Squared value of 0.0298, the trend of yearly total monsoon rainfall is declining over the examined area

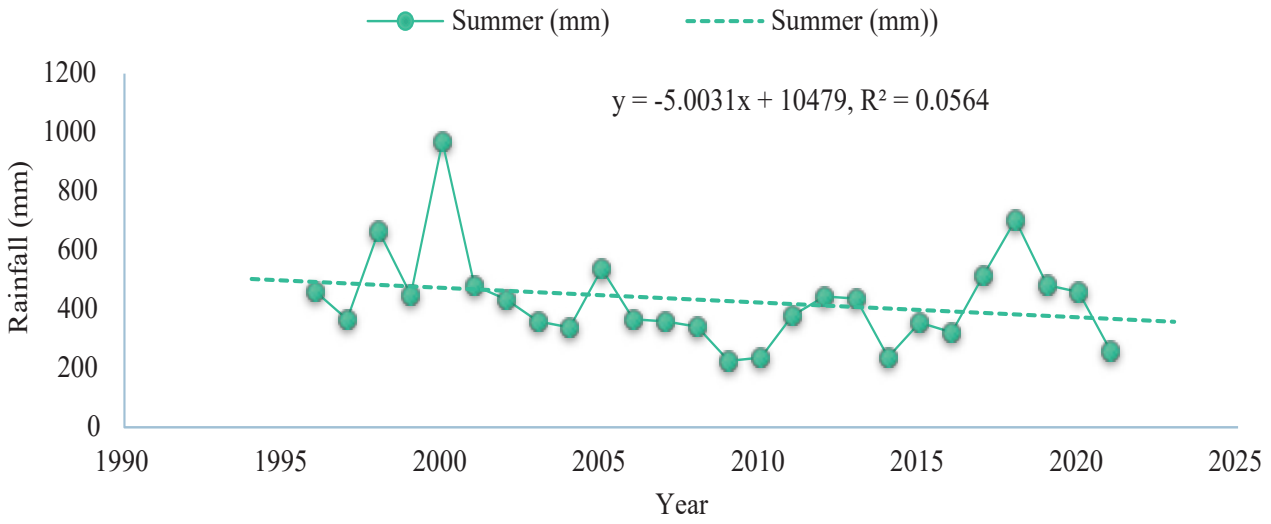


Figure 1. Analysis of the trend of mean total rainfall in pre-monsoon season of Dhaka city.

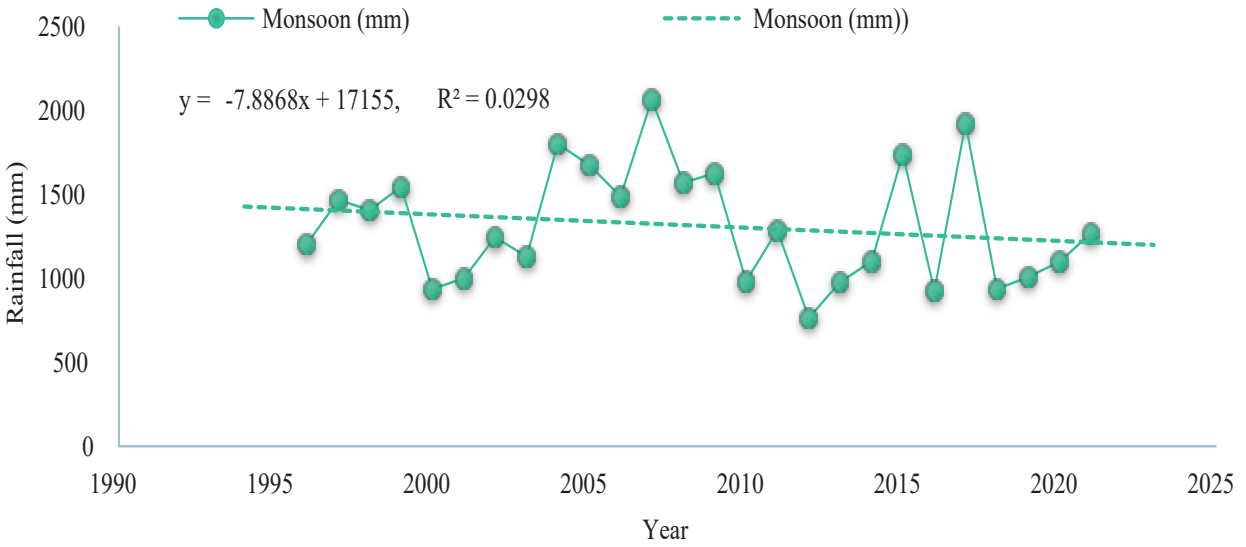


Figure 2. Analysis of the trend of mean total rainfall in monsoon season of Dhaka city.

during the specified period, indicating a negative trend and statistical significance. The annual total monsoon rainfall is declining at a rate of 7.8868 mm/year, as illustrated in Fig 2. The city's monsoon rainfall has changed significantly.

Total post-monsoon rainfall ranges from a minimum of 31 mm in 1997 to a maximum of 431 mm in 2007. The trend of the average annual rainfall has been examined in this study. Over the specified period, the yearly total post-monsoon rainfall trend is declining over the analyzed area; this is a negative trend that is statistically significant, with an R-Squared value of 0.0165. At a rate of 2.1453 mm/year, the annual total post-monsoon rainfall is declining, as seen in Fig 3.

We found that the total lowest rainfall in 1999, 2004, and 2006 was 0 mm, while the greatest annual total winter rainfall in 2021 was 153 mm. The yearly average rainfall trend has been examined in this study. With an R-Squared

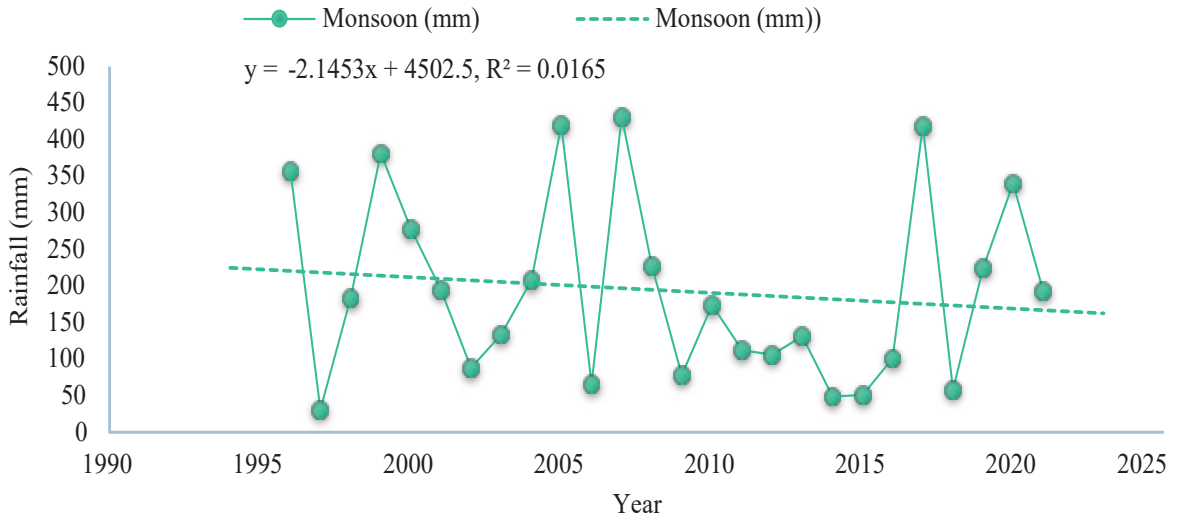


Figure 3. Analysis of the trend of mean total rainfall in post-monsoon season of Dhaka city.

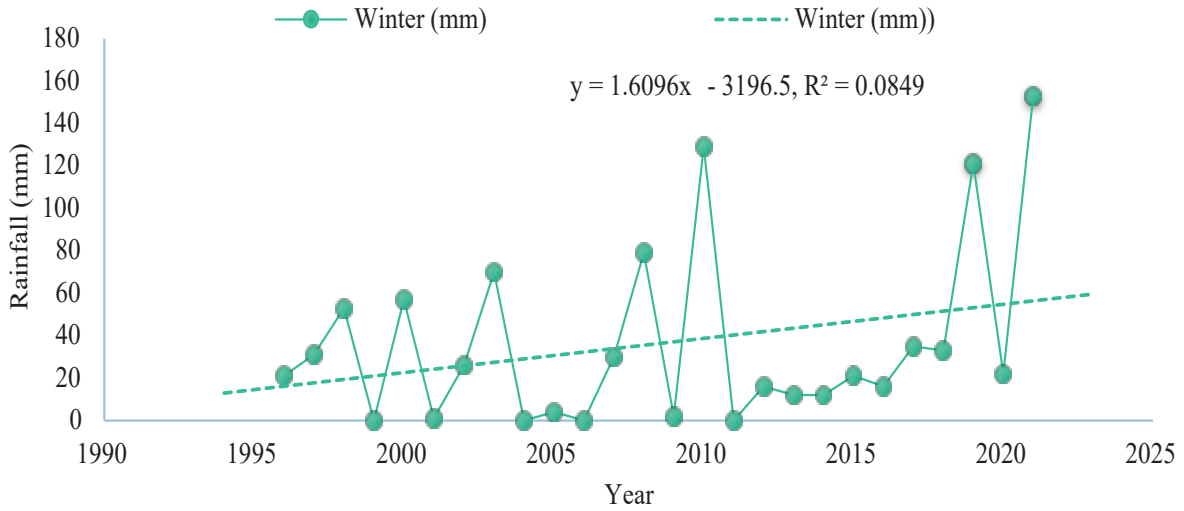


Figure 4. Analysis of the trend of mean total rainfall in winter season of Dhaka city.

value of 0.0849, the trend of annual average rainfall is rising over the examined area over the specified period, indicating a positive trend and statistical significance. The yearly total winter rainfall is rising at a rate of 1.6096 mm/year, as seen in Fig 4. The city's winter rainfall has changed significantly. It also suggests that the city's weather and climate have changed significantly. The winter rainfall has increased dramatically in the last few years.

Observing the data, we have found that the maximum rainfall was 969 mm in summer in 2000, 2065 mm in Monsoon in 2007, 431 mm in Post Monsoon in 2007, and 153 mm in winter in 2021. The minimum rainfall was 225 mm in summer in 2009, 764 mm in Monsoon in 2012, 31 mm in Post Monsoon in 1997, and no rainfall in winter in 1999. The average rainfall throughout the period was 429.85 mm in summer, 1314.65 mm in Monsoon, 193.65 mm in Post Monsoon, and 36.31 mm in winter.

It was evident that Monsoon is the highest rainfall period and winter is the lowest rainfall period.

The Linear regression line is and the value of is 0.0564 in summer. It shows a downward trend.

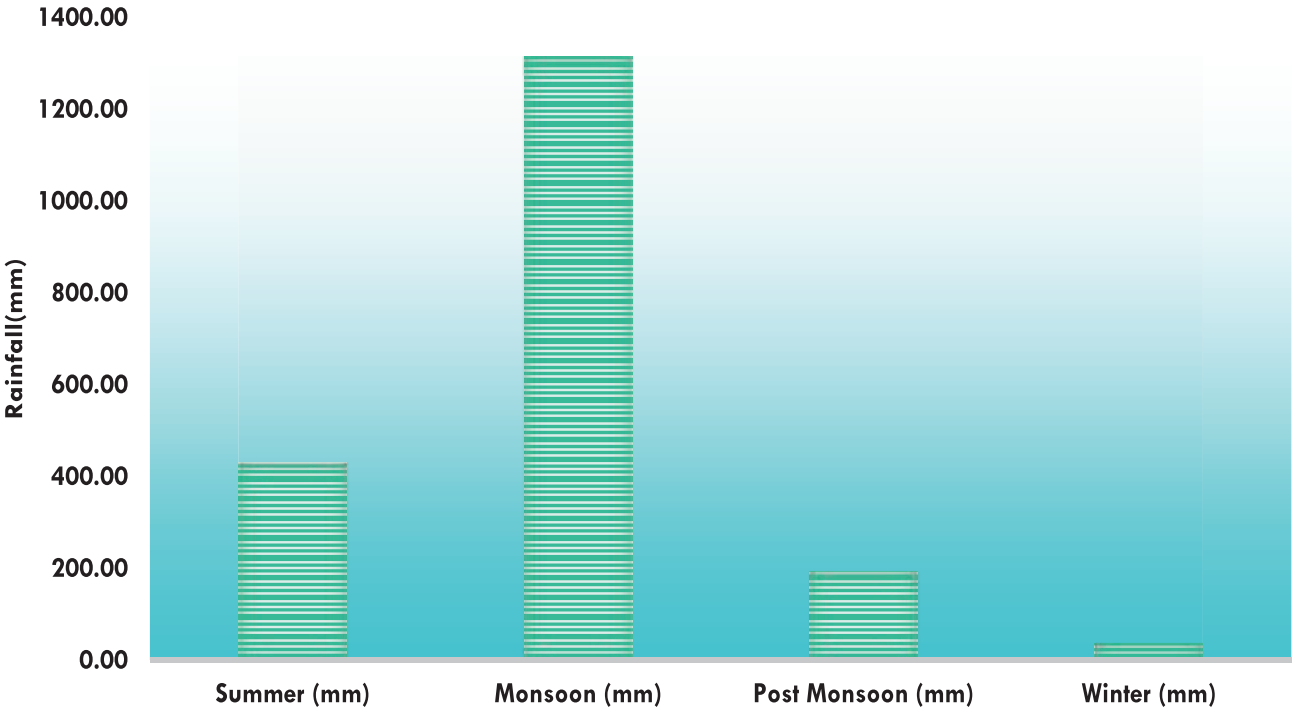


Figure 5. Analysis of mean total rainfall in different seasons of Dhaka city.

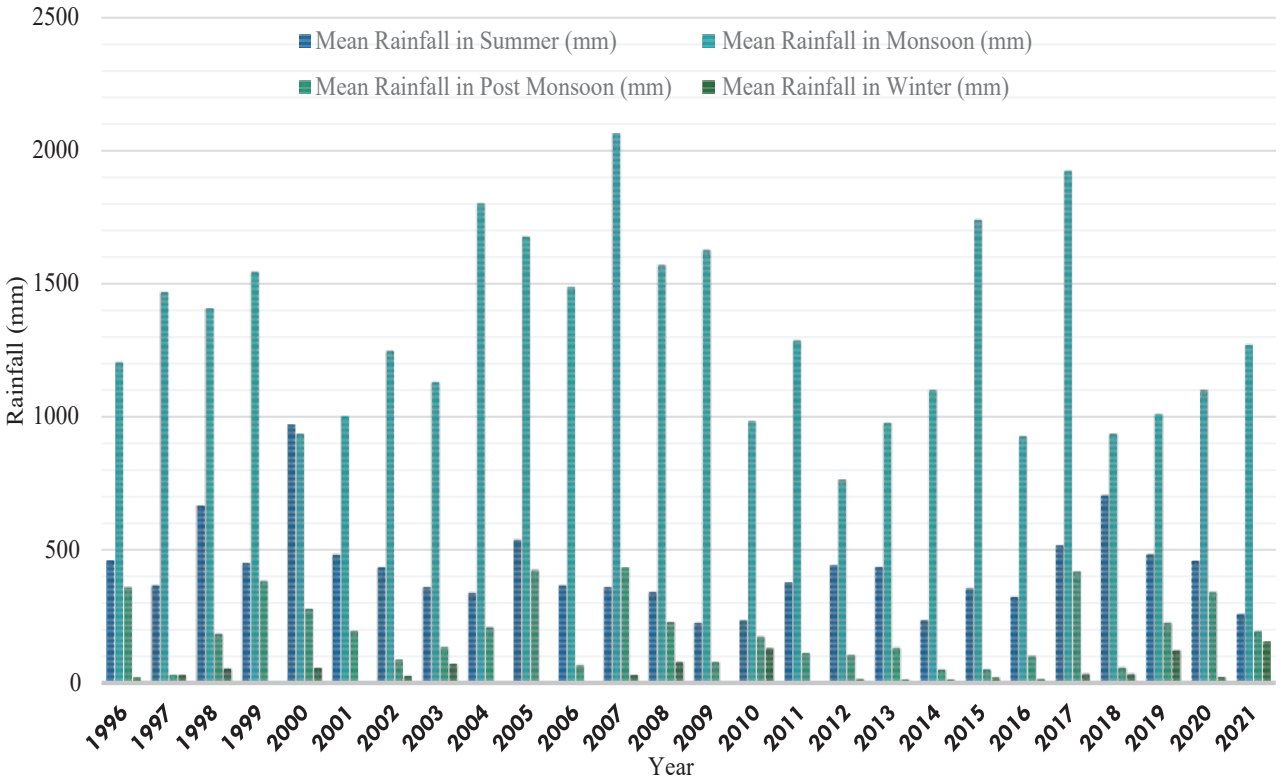


Figure 6. Analysis of the seasonal rainfall of Dhaka city.

Table 1. Relation between meteorological parameters

Parameters	Correlation coefficient (r)
Pre-monsoon vs monsoon rainfall	-0.218561472
Post-monsoon vs monsoon rainfall	0.388246857
Rainfall vs humidity	
Annual (monthly data)	0.693356088
Annual	0.435361262
Pre-monsoon	0.610923751
Monsoon	0.376780227
Post-monsoon	0.598688162
Winter	-0.084064364
Rainfall vs temperature	
Rainfall vs Temperature in Monsoon	-0.497483767
Rainfall vs Temperature in Winter	-0.171837211
Rainfall vs Tempeerature in Pre-monsoon	-0.641475807
Rainfall vs Temperature in Post-monsoon	-0.103831093
Rainfall vs Temperature Annual	-0.203720852

Conclusion

The recent rainfall trend of Dhaka city was analyzed this study. It was found that the tread of rainfall in Dhaka city is declining. Though the average annual rainfall is declining, The yearly winter rainfall is increasing. The rainfall pattern indicates that the future climate will vary in the Dhaka city area.

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