Rainfall prediction in the Southeastern region of Bangladesh using the Linear Regression Method

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Abstract

Globally, there is a lot of concern about climate change. This study sets out to explain how historical rainfall variations occurred. Pre-monsoon and early monsoon regions will become drier in the future, whereas late monsoon and post-monsoon regions will experience significant variations in rainfall amounts. For meteorologists, predicting rain is a particularly challenging task. In recent years, a variety of models have been applied to assess and accurately forecast rainfall. Climate records can be quite helpful in this regard. Retaining data for a long time can help us predict rainfall more precisely. In this paper, the application of statistical techniques, in particular the linear regression and SVM method is provided for modeling and predicting rainfall across Bangladesh. The rainfall data for the 31 years was provided by the Bangladesh Meteorological Department (BMD), Dhaka. Between 1989 and 2019, this surface-based rain gauge in Bangladesh gathered rainfall data from 8 metrological stations. How much rain falls each month and year has been determined. For each station, the average, median, correlation coefficients, and standard deviation were calculated to evaluate the correctness of the data. It was found that the model's rainfall forecast provided reliable results when the amount of rainfall projected by the model was compared to the amount of rainfall measured by rain gauges at various locations.

Keywords
Rainfall, Linear Regression, SVM, Correlation Coefficient and Meteorological Station.

1. Introduction
There is strong evidence that rainfall patterns have changed on both global and regional scales (M. Hulmeet al. 1998; G. Fu et al. 2010). Extreme rainfall may cause floods and waterlogging which in turn may lead to crop failure. Bangladesh is a flat, low-lying nation, making it particularly susceptible to natural calamities (Khan 2013; R. S. J. Tol 2013). Changes in rainfall patterns have a great influence on both crops and human health as well as their impact on the environment. Rainfall is an important climatic factor that can have wide-ranging effects on a nation's agriculture (M. Hossain et al. 2014). There are numerous instances of climate extremes related to rainfall that have had an impact on Bangladesh's agricultural output (Aziz et al. 2014; J. K. Basak 2011). However, decreases in rainfall totals as well as regional and temporal fluctuations have an impact on crop output not only in Bangladesh but also globally (J. De Dios Miranda et al. 2009; M. Hossain et al. 2014).

Figure 1. The geographical location of Bangladesh in the world.

For instance (K. Basak et al. 2013; S. Farhana 2011) only looked at the trends of the various seasons and found that total rainfall showed a growing tendency throughout the monsoon and post-monsoon seasons while a decreasing trend was seen during the winter. Some researchers focused on the intensity and frequency of rainfall, finding that there was a wetter monsoon and a drier winter (Z. Hasan et al. 2014), with more rainy days occurring more frequently in June but heavy rainfall occurring more frequently in July (Mannana et al. 2015).Rahman and Latah (R. Rahman and H. Lateh 2015) found a negative tendency in the average rainfall during the pre-monsoon, which contrasts with the findings of Shahid(S. Shahid 2010; Z. Hasan et al. 2014) in cases of temporal and spatial variability. Few researchers (S. H. Bari et al. 2015) used various analytical methods to forecast the magnitude of future rainfall trends. The historical monthly average and monthly maximum rainfall changes for the years 1975 to 2014 have been studied extensively. Forecasting future rainfall is very difficult as the data are multidimensional and non-linear (S. H. Bari et al. 2015). This study aimed to disclose historical monthly averages and maximums during that period. Bangladesh's subtropical humid climate is marked by significant seasonal fluctuations and is predominantly a low-lying plain region of around 144,000 square kilometers, located on the deltas of huge rivers coming from the Himalayas (S. Banik et al. 2008). Bangladesh's geographic location is frequently mentioned in the production of weather phenomena and disasters. Bangladesh is a deltaic country at the tip of the Bay of Bengal, which has the shape of a funnel Figure 1, (Mallika Roy 2013). This unique geographic setting is largely responsible for the development of cyclones, floods, droughts, tornadoes, high rainfall, and other weather-related events. As a result, rainfall is detected instantly using the weather radar of the Bangladesh Meteorological Department (BMD) and 35 rain gauges spread around the country. The major goal of this project is to identify a rainfall forecasting trend that will be useful for flood forecasting, estimating heavy rainfall, and providing early warning of severe weather. Estimating rainfall is crucial in this regard during crucial times, with the monsoon, pre-monsoon, or post-monsoon being particularly highlighted (Mallika Roy 2013; Elbeltagi 2022).

1.1 Objectives

Climate change is currently an important global issue, and various organizations are reviewing this issue with great importance. Many studies are being conducted on the issue of global warming. Accordingly, we also observe variations in rainfall in different regions as part of climate change. Changes in rainfall significantly impact agriculture and living in a country. The purpose of our research article is, we use the amount of past rainfall in the southern part of Bangladesh to determine the type of rainfall in those areas in the future. And we have tried to reach as close to the correct value as possible with the help of the Linear Regression Method.

2. Literature Review

In Bangladesh, the four primary meteorological seasons is winter, pre-monsoon, monsoon, and post-monsoon. Pre-monsoon and post-monsoon refer to the time between the SW-monsoon (monsoon) and the monsoon (winter). The nation's average temperature varies from 26.9 to 31.1 °C in the summer and from 17.6 to 20.6 °C in the winter. In Bangladesh, the annual average relative humidity ranges from 70.5 to 78.1 percent (Mohammad Shohidul Islam 2013). During the monsoon season, the humidity is over 84 percent, but in other months it is just about 55 percent (Figure 2). Bangladesh's Seasons: a. inter (December to February) There are three seasons: pre-monsoon (March to May), monsoon (June to September), and post-monsoon (September to October). The hills in this area are strongly related to and responsible for the heavy rainfall, tea gardens, dense bamboo, and cane bushes, high flood plains, and flashy rivers (Islam 2003; Shahriar et al. 2021).

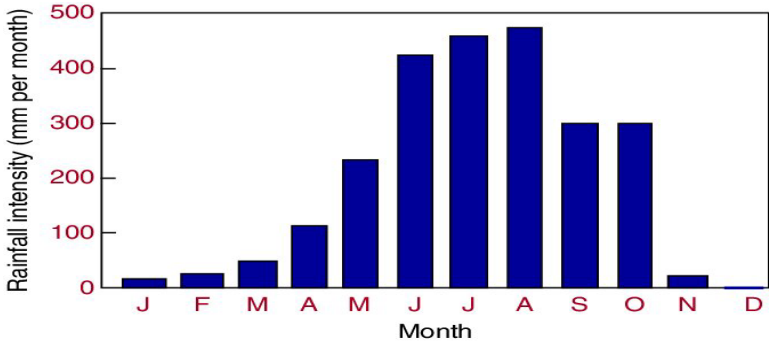

Figure 2. The graph of Bangladesh's average monthly precipitation (1989–2019).

A power regression-based long-range summer monsoon rainfall forecast model that considered the el Nino, Eurasian snow cover, northwest Europe temperature, Europe pressure gradient wind pattern, Arabian sea SST, east Asian pressure, and south Indian ocean temperature was presented by N. Sen. the year before (Islam et al. 2005; Aziz et al. 2022). According to the experimental findings, the model error was 4% The creation of a statistical forecasting method for SMR over Thailand utilizing multiple linear regression and regional nonparametric approaches was discussed by S. Nkrintra (Di Nunno et al. 2022). In the highlands of Eritrea, M. T. Mebrhatu developed a model for predicting rainfall categories (below, above, and normal) (Guhathakurta 2005). A model for predicting human height based on several polynomial regressions has been utilized successfully to accurately predict the height of the growth potential of youngsters (Fabio et al. 2022). Using multivariable polynomial regression, Vaccari modeled plant motion time series and nutrient recovery data for advanced life support (Yaseenet al. 2021).

We have read many articles about rainfall forecasts, but they have yet to yield the desired results. We have gotten a reasonably accurate value. And we have also attempted to determine the approximate amount of rainfall in the southern part of Bangladesh in the future, where the Linear Regression Method has been used. And this article will be helpful to many people. We expect that the demand for it will also increase in the future.

3. Study area & Data

3.1 Study Area

The south-eastern region of Bangladesh, which is a portion of the Chittagong region, was chosen as the study location for this research (Figure 3). The region around Chittagong has quite an intriguing terrain. Fantastic lakes, lovely hills, little forests, solitary islands, and plain regions are all present in the area. The second-largest city in Bangladesh and a bustling international seaport is Chittagong.

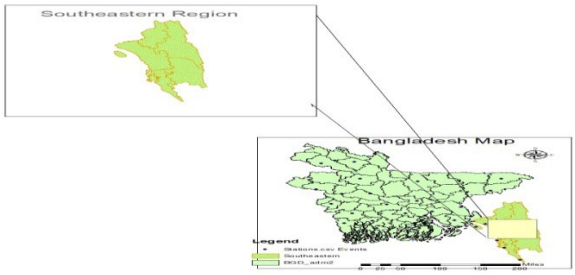

Figure 3. The study area in light green on a map and the Southeastern region.

It is referred to as Bangladesh's commercial capital. Because of its scenic hinterland of sizable hill forests and lakes, Chittagong is a nice destination for vacations. Visitors are always drawn to the area by its verdant hills and forests, wide, sandy seashores, and pleasant, temperate climate. With its undulating landscape, it mixes the hum of a bustling harbor with the enjoyment of a lovely hill town.

3.2 Data

A long-term recorded climatic dataset was employed in the current analysis. The rainfall data were gathered in Bangladesh's Chittagong region. The Bangladesh Meteorological Department (BMD) provided rain gauge rainfall over the research region from the years 1989 through 2021. The information was gathered from BMD stations and comprised observations of the 03 hourly and daily rainfall accumulations at several rain gauge sites.

4. Methods

The linear relationship between a predicated (dependent variable) and predictors is modeled using the linear regression (LR) method (one or more independent variables). It is common practice in climatology to utilize this model, which is based on least squares, to create models for the reformulation of climate variables from tree-ring records. Estimates of the predicted variable outside the period used to fit the data are created using the regression model. Confidence intervals, which may be calculated in a variety of different ways, provide a summary of the reformation's level of uncertainty.

4.1 Linear Regression Model

The least squares method, which is the most popular one, is used to fit the linear regression line. By reducing the sum of the squares of the vertical deviations between each data point and the line, this method calculates the line that fits the observed data the best. The algebraic sum of the residuals is zero if a point exactly sits on the straight line (S. Banik et al. 2008). The discrepancy between an observation at a certain time and the value extrapolated from the trend line at that same time is known as a residual. A linear regression line's equation is provided as,

$$y = a + bx \quad \text{..... (1)}$$

Where y is the dependent variable's observation(s)
Observation x is made regarding the independent variables
The least squares method's estimation of the intercept "a" and the regression coefficient "b"

$$\hat{a} = \overline{y} - \hat{b}\overline{x} \quad \text{..... (2)}$$

$$\hat{b} = \frac{\sum(x-\overline{x})(y-\overline{y})}{\sum(x-\overline{x})} \quad \text{..... (3)}$$

R2 = SS resulting from regression/total SS is the coefficient of determination.

$$ss = \frac{\sum(\widehat{y_i}-\overline{y})^2}{\sum(y_i-\overline{y})^2} \quad \text{.....(4)}$$

The monthly average rainfall throughout the rainy season was plotted against time (an independent variable) in years to fit regression lines. The trends in rainfall were then determined by fitting linear regression lines. Microsoft Excel was used for diagram creation and regression line fitting.

4.2 Intensity Trend

Secular trend, or simply trend, refers to the data's overall propensity to increase or decrease over an extended period (Ghosh, Sanjib 2015; S. Banik et al. 2008). Data on temperature, precipitation, and agricultural output are gathered over time and are consequently referred to as time series data, which is a collection of observations that changes over time. Four elements of the time series are known seasonal, trend, cyclical, and irregular (Patterson, 1987). The term "trend" refers to either the long-term shift in the dependent variable over a significant amount of time or the overall movement of a series over a significant amount of time (Webber and Hawkins, 1980). The 33 years of accessible data from the station were deemed appropriate for the trend analysis because the trend variance happens over a sizable amount of time. Therefore, the stations in Cox's Bazar, Hatiya, and Sandwip were not included in this research. The link between the two variables determines the trend (rainfall and time), to track the monsoon's typical trend. Using the least square method, rainfall for the specified stations and trend data have been determined. According to the simple regression coefficient, Chittagong's annual average rainfall is rising by 0.31 percent.

4.3 Correlation Coefficient

The strength of the linear link between two variables is determined by the correlation coefficient. It always accepts a number between -1 and +1, with a value of +1 or -1 signifying a perfect correlation (in which case all points would lie along a straight line and have a residual of zero). There is no correlation between the variables if the correlation coefficient is close to or equal to zero. The link between the variables is said to be positive (upward) when the correlation coefficient is positive and negative (downward) when the correlation coefficient is negative. The following formulas were used to determine the correlation coefficients between rainfall and time. Given the pairs of values (x_1, y_1), (x_2, y_2),..... (x_n, y_n), the formula for computing the correlation coefficient is given by,

$$r = \frac{\sum(x_i-\overline{x})(y_i-\overline{y})}{\sqrt{\sum(y_i-\overline{y})^2 \sum(y_i-\overline{y})^2}} \quad \text{.....(5)}$$

Using the methodology above, the correlation coefficients for the Chittagong station were determined. Tables 3 and 4 display the outcomes.

5. Results and Discussion

5.1 Analysis of Monthly & Yearly Rainfall

For the eight stations in table 1, some calculations of monsoon average Rainfall Trend Values over Chittagong data from 1989 to 2019. Figure 4 demonstrates that Chittagong's rainfall trend is rising, indicating a positive linear relationship between rainfall and time. Plot with Trend Analysis for Prediction of Chittagong Region's Annual Average Rainfall. According to the R2 value of -1.480, time explains only 9.85 percent of the variation in rainfall. The trend of rainfall was then determined using the strength of the linear relationship between the variable and time. The correlation coefficient calculates these associations. The correlation coefficient for the Chittagong region is 0.091 rainfalls.

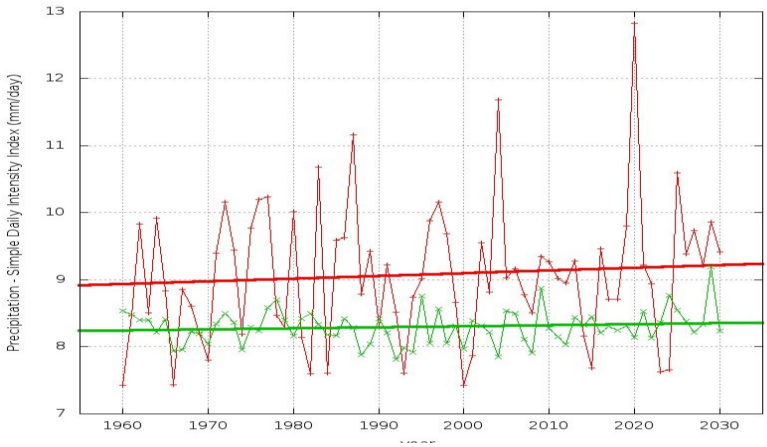

Figure 4. Plot with Trend Analysis for Prediction of Chittagong Region's Annual Average Rainfall.

Figure 4 also shows a linear line pointing higher, indicating that rainfall activity is escalating with time. For annual average rainfall total stations, several statistical metrics such as average, median, correlation coefficient, and standard deviation are determined at the same time.

Table 1. Some Calculations of monsoon average Rainfall Trend Values over Chittagong

Year	Avg. RF (mm)	Trend Values
1989	393.67	420.95
1995	340.00	431.06
1999	514.25	437.80
2002	411.50	442.85
2004	458.75	446.22
2007	647.00	451.27
2008	487.18	452.96
2010	510.31	440.00

Table 2: Correlation Coefficient in Chittagong

Station	Correlation Coefficient
Chittagong	0.091

A correlation coefficient is a statistical indicator of how well changes in one variable's value predict changes in another. When two variables are positively linked, their values either rise or fall together (Table 2).
According to the rising trend for Chittagong, there is a positive correlation between time and rainfall. In Chittagong, the correlation coefficient between rainfall and time is 0.091 (Table 3)

Table 3. Monthly Rainfall Statistics by Station

Statistical Parameters	Value
Average	278.901
Median	278.456
Correlation Coefficient	0.091
Standard Deviation	67.075

Table 4. Prediction performance for the rainfall on the dataset

Model	MSE	RMSE	MAE	R2
SVM	144.150	12.006	10.897	-1.480

5.2 Comparison between Average rainfall and prediction based on SVM model

Table 5 shows the SVM model dataset.

Table 5. SVM Model dataset

Station	Region	Year	Month	Average	SVM model
Chittagong	Southeastern	2002	7	29.677	15.625
Cox's Bazar	Southeastern	2002	12	0.033	15.747
Kutubdia	Southeastern	2011	7	25.903	15.586
Rangamati,	Southeastern	1998	7	12.453	15.488
Shandwip,	Southeastern	1991	7	5.766	15.611
Sitakunda	Southeastern	1989	10	0.132	15.790
Teknaf	Southeastern	1993	8	43.129	15.742

5.3 Rainfall Variation in Bangladesh

According to analysis, rainfall in Bangladesh occurs every 2-3 years, every 6 years, and every 11 years.
The natural reaction mechanism of the ocean-atmospheric system to changes in many physical parameters may be attributed to the yearly variance in monsoon rainfall. This may also be connected to climate changes that can occur because of natural or artificial forces.

5.4 Rainfall Pattern:

The whole year was divided into four seasons to assess changes in rainfall patterns by analyzing changes in total rainfall for the period of 1989 to 2019. The hot season starts from March to May, which is called the pre-monsoon. June to September is the monsoon, and October and November constitute the post-monsoon season. The cold season is from December to February, which is winter. In this study, we observed a significant change in the trends of rainfall. In the winter season of Bangladesh, among the 34 stations, 2 showed an increasing trend while 32 showed decreasing trends in total rainfall. On the other hand, the monsoon season showed a rising trend in 31 stations; 30 stations showed an increasing trend in total rainfall for post-monsoon and 20 stations for pre-monsoon among 34 weather stations. Moreover, the observed trends were not statistically significant in most cases. Nevertheless, most stations showed an increasing trend of rainfall during the monsoon and post-monsoon seasons, while a significant number of stations showed a decreasing trend of total rainfall during winter. From the analysis of total rainfall, we observed that the results are consistent with the general climate change predictions that day periods would become drier and wet periods would become wetter. In Bangladesh from 1989 to 2019, the yearly average rainfall increased in the southern and southeastern regions. while the yearly average rainfall decreased in the remaining regions (the northern, northwestern, north-southern, central, and eastern regions, respectively) which is shown in Table 6.

Table 6. Changes in Amount of Rainfall (mm per year) in four Seasons during 1989-2019

Region	Winter	Pre-monsoon	Monsoon	Post-monsoon
SouthEastern	-0.489	-0.193	4.095	-1.541

Table 7. Finding the Standard Deviation Step by Step

Stations	Monthly Avg Rain (X)	Mean Avg Rain (M)	X-M	$(X-M)^2$	Standard Deviation
Teknaf	414.83	319.381	95.45	9110.7	67.075
Cox's Bazar	370		50.62	2562.38	
Hatiya	320.16		0.78	0.6084	
Kutubdia	324.5		5.12	26.2144	
Rangamati	196.75		-122.63	15038.1	
Sandwip	355		35.62	1268.78	
Ambagan	260.66		-58.72	3448.04	
Sitakunda	313.16		-6.22	38.6884	

Table 7 shows that the linear line is pointing upward for most of the stations, including Cox's Bazar, Sandwip, Kutubdia, and Ambagan, while the line is pointing downward for Hatiya and Rangamati. This indicatesthat the rainfall activity is waning with time at Hatiya and Rangamati. The average monthly rainfall for each station is also determined at the same time using various statistical criteria.

6. Acknowledgment

First and foremost, praise be to the Creator, by whose grace our paper was completed without major setbacks. We appreciate Dr. Ganesh Chandra Ray, our supervisor, for his kind assistance and proper guidance throughout our efforts. He came to our aid anytime we needed him. Every time we encountered a challenge, he was nothing but practical and supportive. And we are also grateful for the information provided by the Bangladesh Meteorological Department (BMD).

7. Conclusion

Property management may require the assessment and division of landslide vulnerability. The specified land division, as well as any applicable policy and legal provisions, should be followed in the planning, land usage, and use. In Chittagong, the majority of landslides occur when the severity of the season's precipitation is at its highest. To assess the situation, rainy seasons should be regularly watched, especially in landslide-prone areas. People in the affected communities should receive early warnings in the event of any hazardous landslides. Correct land usage and property land management should be included in awareness campaigns as well. An appropriate flood prediction system that can provide accurate forecasts during floods with enough lead time is a recognized key element in adaptation to increased floods brought on by global climate change. Flooding injuries can be reduced by making changes to the surrounding buildings and infrastructure. Flood fighting techniques have been used during floods to prevent damage to the failure of control structures. Fighting floods is an urgent means of reducing their effects on society and the environment, particularly when management measures have proven inefficient or ineffectual. Wherever the structures or other options don't provide a haven during a flood, evacuation is crucial. The government should set aside a decent sum of money in the event of climate change to aid in flood relief as a reasonable way to live. The cost of flood damage is frequently managed by requiring flood insurance. It is currently available in some nations with sophisticated insurance markets.

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Biography

Md Habibur Rahman graduated in Applied Mathematics from the University of Chittagong. Now he is working as a Teaching Assistant at Youth Society for Research & Action (YSRA). He is a member of IEEE and Organizing Secretary at IEEE Chittagong University (CU) Student Branch. His research interests are applied mathematics, data science, machine learning and artificial intelligence. He is also working as a Research Assistant with last two years of experience working alongside the executive Machine Learning/AI field. He has attended several conferences and given successful research paper presentations online and in person. He already had a conference paper published in IEEE. In addition, he is a gold award winner of Univ's 2nd International Competition for Young Researchers 2022, where he presented his research titled "Trends, Perspectives, and Prospects in Machine Learning." He inspired daily by his supervisor and their two students. Recently he joined as a Research Assistant at Dr. Jamal Nazrul Islam Research Center for Mathematical and Physics, University of Chittagong. In his free time, he likes to hike, crochet and play video games with his friends.

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Abir Ahmed Rifat graduated in Mathematics at University of Chittagong, Bangladesh. He just has finished his MS in Applied Mathematics from same University. He is currently doing a project in Advanced relativity under his department professor Dr Ashraful Islam. He has been involved in research last one year. he worked on some papers and projects. His research interests are applied mathematics, data science, machine learning and artificial intelligence. he wants to go abroad for higher study. Now he is taking preparation for his higher study and working on hisself to make a competitive profile so that he can get scholarship.