Rainfall Time Series Analysis

A DISSERTATION

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THE AWARD OF THE DEGREE OF

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MATHEMATICS

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DECLARATION

We, Prusha (2K21/MSCMAT/36) and Riya Kadian (2K21/MSCMAT/62), students of M.Sc. Mathematics, hereby declare that the project Dissertation titled "Rainfall Time Series Analysis" which is submitted by us to the Department of Applied Mathematics Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Science, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "Rainfall Time Series Analysis" which is submitted by Prusha (2K21/MSCMAT/36) and Riya Kadian (2K21/MSCMAT/62) [Department of Applied mathematics], Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Science, is a record of the project work carried out by the students under my supervision. To the best of my Knowledge this work has not been submitted in part or full for any degree or diploma to this university or elsewhere.

Place : Delhi	**Prof. L.N. Das**
Date :	**SUPERVISOR**

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ABSTRACT

It is now generally acknowledged that greenhouse gas emissions are to be blamed for the rise in the global average temperature. Changes in the frequency of extreme weather occurrences, such as catastrophic floods, storms, and droughts, may indicate global warming drought. On a global scale, the subject of climate change is being discussed. In the age of climate change and global warming, we set the goal of this study to analyse the rainfall trends in Cherrapunji. Data on the station's monthly rainfall is gathered from the official website of Cherrapunji Holiday Resort. The average rainfall of the 48 years is observed and the graphs are plotted showing the monthly rainfall time series of Cherrapunji over a time period of 48 years along with the linear trendline, trendline equation and R-squared value where R-squared value is a measure of the trendline reliability. The R-squared value is compared and the time series graphs are analysed month wise and season wise. Since Cherrapunji receives heavy rainfall throughout the year, so we broke down the data into five seasons and also carried out the seasonal analysis of rainfall. This station was chosen because it had more readily available data and it represented the area with the most rainfall records.

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Chapter 1

INTRODUCTION

Changes in rainfall patterns directly affect water availability since rainfall is an essential part of the hydrological cycle. The altered rainfall pattern brought on by climate change is currently causing worry among water resource managers and hydrologists. The demand for and pattern of stream flow, the spatiotemporal distribution of runoff, ground water reserves, and soil moisture are all directly impacted by variations in rainfall volumes and frequency, according to Srivastava et al. and Islam et al.Dangerous occurrences like drought and floods may be common because of the notable fluctuations in rainfall trends.

Rainfall during the monsoon season is essential for Indian agriculture. Rain-fed agriculture accounts for 68% of India's total arable land, 60% of which is used to feed the country's cattle population and 40% of which is used to support its human population. Approximately 70% of India's population resides in villages, according to Census of India 2022 (www.censusindia.gov.in). Primarily in rural areas,agriculture and cultivation are occupations. The key factor affecting agriculture is precipitation and rainfall. In addition to this, rainfall is largely dependent on activities that require water. As a result, factors like rainfall patterns and extreme rainfall occurrences are crucial. [7] Rainfall research is an important topic of study in meteorology, hydrometeorology, and hydrology. The sustainable development of agriculture in India therefore requires extensive research on the detection and monitoring of climate change. The ability of communities to adapt to severe weather events may be improved and decision-making can be facilitated most significantly by having a full understanding of how precipitation patterns change with the environment.

Farmers have taken drastic measures, even committing suicide, as a result of the bizarre weather's devastation on the farming community. In India, there were 300000 farmer suicides between 1995 and 2014. Therefore, it is important to assess if rainfall trends and variability patterns are present.

As a result, the primary objectives of hydrology, climatology, and meteorology study throughout the globe have been to analyse rainfall variability, pattern changes, and the presence of trends over a variety of geographic horizons.In the past, various attempts have been made in India to identify regional and statewide trends in rainfall.Trend analysis study has been regarded as a helpful technique since it offers important information regarding the likelihood of future changes.

To carry out the best planning while taking into account upcoming changes in climatic elements, planners are better served by future forecasting. Understanding the recent and historical climate changes is aided by trend analysis. [5]

Monsoon systems dominate the Indian climate. Southwesterly winds transport moisture from the Indian Ocean during the northern hemispheric summer, resulting in significant rains in India from June to September. The climate of India is widely classified into five seasons, which are mostly defined by seasonality in rainfall.

- Winter (December and January)
- Spring (February and March)
- Pre-Monsoon (Summer) (April and May)
- Southwest monsoon (June to September)
- Post-monsoon (Autmn) (October and November)

About 75–80 % of the nation's yearly rainfall is attributed to the summer monsoon (also known as the southwest monsoon). One significant aspect of monsoon rainfall is the migration of depressions/storms that originate over the Arabian Sea or the Bay of Bengal.

1.1 Our Contribution and Objective

In this paper, we have collected the data of last 48 years of rainfall in Cherrapunjee (1975-2022). The main objective in this paper is to examine:

1. The Monthly trend of rainfall over the last 48 years.

2. The Seasonal trend of rainfall over the last 48 years.

using time series analysis and further compare the R^2 values of the time series graphs.

Chapter 2

LITERATURE REVIEW

2.1 Time Series Analysis

A set of qualitative observations that are arranged chronologically are referred to as time series. Time is usually seen as a discrete variable. There are several data sources that use observations that were made over a long period of time and in succession.In the realm of business, we monitor things like weekly interest rates, daily closing stock prices, monthly price indexes, and yearly sales figures. The daily high and low temperatures, yearly precipitation and drought indices, and hourly wind speeds are all monitored in meteorology. In agriculture, we track annual figures for crop and livestock output, export sales, and soil erosion. In the biomedical sciences, millisecond intervals are used to track the heart's electrical activity. A species' abundance is monitored in ecology. A almost infinite number of areas do time series research. Time series analysis frequently has two objectives: to explain or model the stochastic process that results in an observed [2]

The following equation may be used to mathematically obtain the time series: y=f(t), where t is the independent variable time and y is typically the response to the time over the function.

Other major Aspects

- **Stationary:** when the statistical characteristics of a function that depends on variable time remain constant across time and the function is stationary. Or, to put it another way, we presume that the mean and variance are constant given steady characteristics.

- **Seasonality:** Seasonal and correlated with the seasons of the year are periodic fluctuations across time. Residential energy use, which changes during the day and night, is the finest illustration of these traits. At night, household consumption is at its highest; during the day, it dramatically declines. Consequently, a graph will show that the function's peak value fluctuates with time. .

- **Autocorrelation:** Autocorrelation is the resemblance between two or more observations that were made at different times. This offers significant insights on how to evaluate time series patterns.

Having seen the aforementioned traits, it is feasible that the graph we have has a mixture of the traits we have seen thus far.

2.1.1 Terminology

A time series is deemed to be **continuous** when observations are taken over an extended period of time. Even though the measured variable may only accept a discrete range of values, the word "continuous" is used for series of this kind. The term **discrete** refers to a time series in which observations are only recorded at discrete, frequently evenly spaced periods. Even when the measured variable is a continuous variable, series of this kind are nonetheless referred to as such.

Discrete time series can happen in many different circumstances. From a continuous time series, we might extract data at predetermined intervals to produce a discrete time series, sometimes referred to as a sampled series. There is a special form of discrete series that is produced when a variable doesn't have an instantaneous value but we may sum the values over equal time periods. Monthly exports and daily rainfall are two examples of this kind.

The concept of random sampling of separate observations is central to much of statistical theory. The unique characteristic of time series analysis is that it requires consideration of the time order of the observations and that subsequent data are typically not independent from one another. Future values can be anticipated from past values when subsequent observations are reliant on one another. A time series is considered deterministic if it can be anticipated with ease. Since accurate predictions are difficult due to the stochastic nature of most time series, it is necessary to substitute them with the notion that future values will follow a probability distribution that will depend on knowledge of past values.

2.1.2 Objectives of Time series Analysis

The analysis of a time series might have a variety of goals.These goals can be categorised as control, explanation, prediction, and description goals.

1. *Description*

   Typically, a time plot is created as the first step in the analysis of a time series, from which straightforward descriptive measures of the series' essential properties may be derived.

   Anyone trying to evaluate the time series without first preparing it will likely run into problems.A graph will show seasonal variation and trend in addition to any missing observations, outliers, and irrational observations that don't appear to fit the rest of the data. Other qualities to look for in a temporal storyline are changes in the series' features that happen suddenly or gradually.If the series contains some sort of discontinuity, individual pieces may require fitting with different models.

2. *Explanation*

   If two or more variables are observed, it could be feasible to use the variance in one time series to explain the variation in another series. This could lead to a clearer understanding of how a certain time series was created.

3. *Prediction*

   We could wish to forecast future values of a time series based on its observed values.

4. *Control*

   To enhance control over physical systems, time series data may be gathered or examined. The complexity and style of control processes might differ greatly. [1]

2.2 Time Series Analysis History

Problems of casuality often arise when analyzing time series.
What impact did the past have on the present? Sometimes, rather of being classified as a subfield of time series analysis, such problems (and their responses) are studied solely inside that area. As a result, new perspectives on time series data sets have emerged from a variety of fields.

We look at a few historical instances of time series data and analysis in the following fields in this section:

- Medicine
- Weather
- Economics
- Astronomy

Forecasting Weather : For obvious reasons, predicting the weather has long piqued people's curiosity. Aristotle, a pre-Renaissance Greek philosopher, devoted his whole work, Meteorology, to the study of weather. Up to the Renaissance, these theories concerning the causes and dynamics of weather were widely accepted. In order to monitor atmospheric conditions using newly developed devices like barometers, scientists started gathering weather-related data at that time. With the use of these tools, time series were logged on a daily or hourly basis. Personal diaries and local city records were only two examples of the many places records were stored. In Western civilisation, this has been the only method of weather monitoring for ages.

After several atmospheric observations were put to use in the late 19th century, the telegraph allowed for the instantaneous recording of atmospheric conditions throughout time from various locations. By the 1870s, this method had become commonplace over most of the world, and it was the catalyst for the development of the first useful databases for forecasting local weather using information from other regions. Connected.

The notion of using these gathered datasets to forecast weather using computer methods was extensively pushed in the early 20th century. Early attempts to predict the weather included a lot of work, but the outcomes were disappointing. It was impossible to apply all of the recognised theories about the underlying natural principles that physicists and chemists had developed at the time. Anyone attempting the resultant equation system for the first time would find it to be an astounding scientific discovery due to its complexity.

Physical equations may be made simpler in ways that improve accuracy and computing efficiency, according to decades of study. These clever methods have been included into modern weather forecasting models, which combine well-known scientific concepts with tried-and-true heuristics.

These predictions include exact information about the position and amenities of weather stations. Many governments now monitor the weather in great detail using data from hundreds or even thousands of weather stations throughout the globe. Using information that The origins of this endeavour may be traced back to the 1870s adjusted data sets and, even earlier, to the Renaissance custom of maintaining a local weather diary. Unfortunately, one illustration of the growing attacks on science that also includes time series forecasting is weather forecasting. It politicises less important time-series forecasting jobs like predicting the route of storms in addition to the global temperature time-series discussion.

2.3 Importance

The Importance of Time Series is as below:

- For many companies, it is useful to predict the evolution of business profit and loss. In this way, important business decisions drive development.
- By comparing current trends with past trends that have already occurred, you can anticipate and prepare for future trends.

- Cycle variation over time using time series can be very effective in understanding economic cycles.
- It helps you understand correlated seasonal trends in your data.
- It is also useful in the quality control process to predict quality trends over time.
- Once you have a complex signal pattern, you can apply transformations such as Fourier analysis to denoise the graph and split the complex pattern into many simpler patterns for better understanding.
- It is also useful to understand how the characteristics of events change over time. Therefore, reliability, flexibility and other important characteristics can be predicted.

2.4 Real-life applications

Temporal data, or items that change over time or are influenced by it, are studied using time series analysis. Due to the ongoing fluctuation of currencies and sales, time series analysis is frequently employed in the financial, retail, and economic sectors. Time series analysis is used effectively in stock market analysis, particularly when automated trading algorithms are used. Time series analysis works similarly well for predicting weather changes, assisting meteorologists in forecasting everything from tomorrow's weather to future climate change. Time series analysis in action is demonstrated by:

1. **Retail Sales** : Time series analysis is frequently used by retailers to examine how overall sales evolve over time.

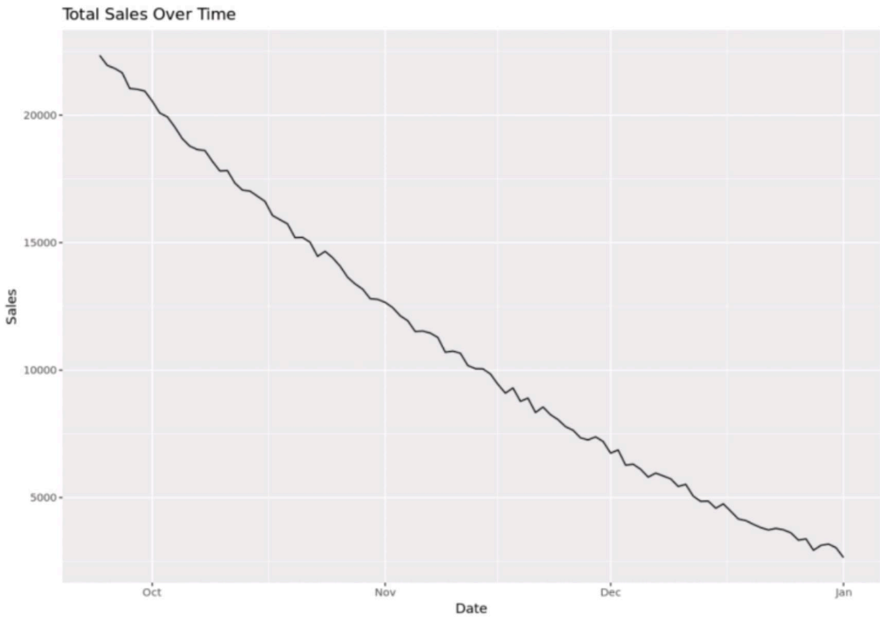


Figure 2.1: Sales

Analysis of monthly, seasonal, and annual sales trends benefits greatly from time series analysis.

Retailers will be able to better correctly anticipate sales for upcoming periods as well as inventory and personnel demands throughout the year as a result.

2. **Stock Prices** : Stock traders frequently utilise time series analysis to analyse diverse stock price trends on a deeper level.

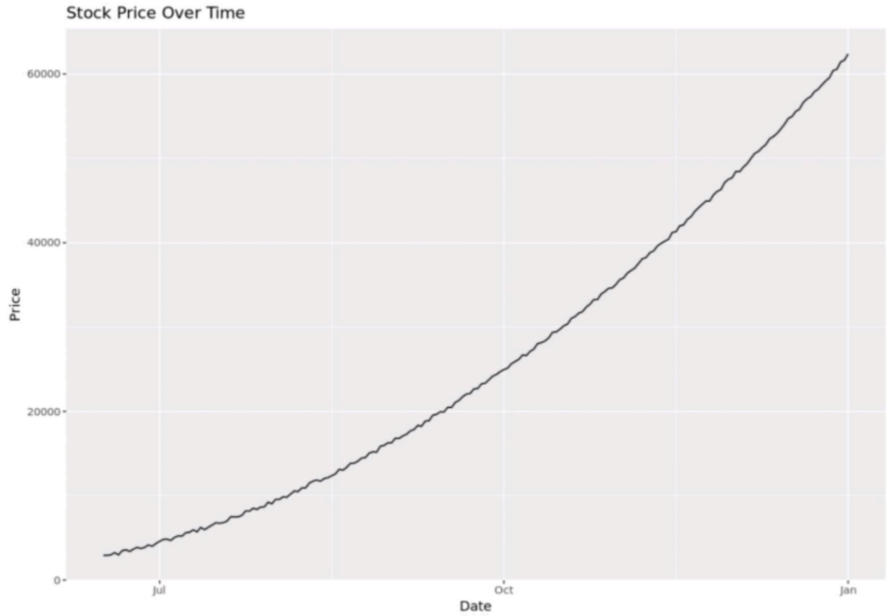


Figure 2.2: Stock Prices

Time series charts are particularly useful for stock analysts and traders as they allow them to understand the trend and direction of a particular stock price.

3. **Weather** : Weather forecasting for various months and seasons of the year is another prominent use of time series analysis.

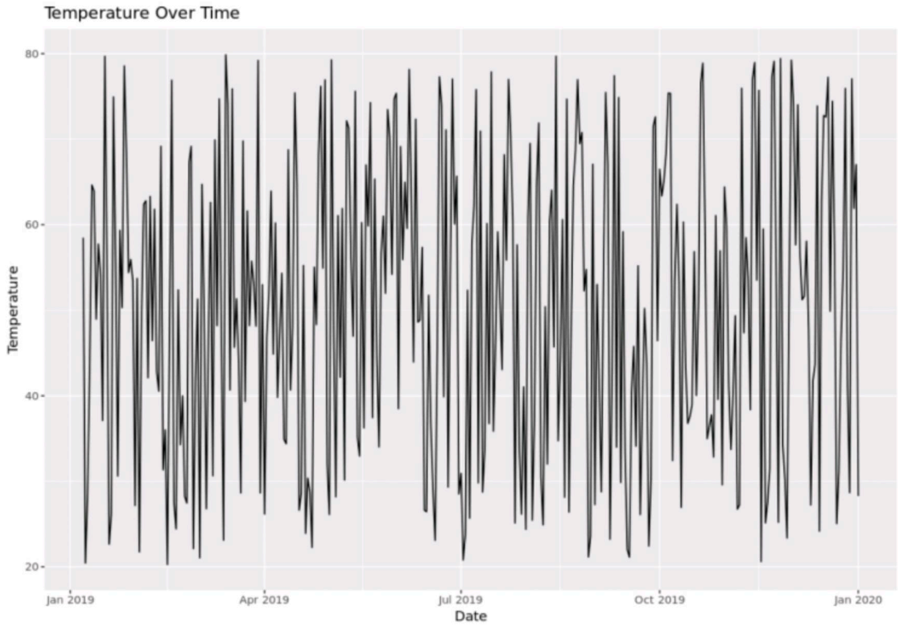


Figure 2.3: Temperature over Time

4. **Heart Rate** : Time-series analysis is also used in medicine to keep an eye on patients' heart rates who may be taking specific drugs to make sure that their heart rates don't change a lot during the day.

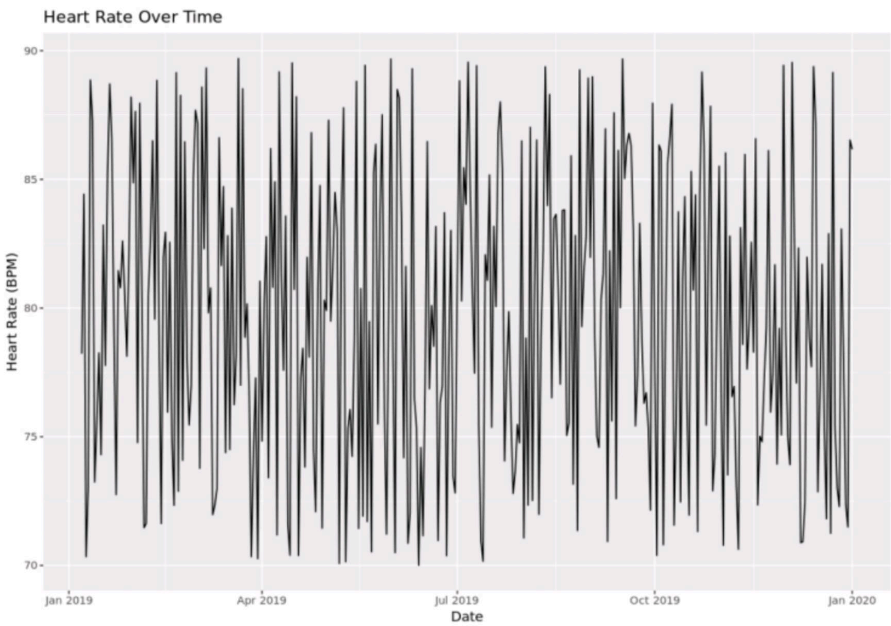


Figure 2.4: Heart Rate over Time

5. **Subscribers** : In online publishing, time series analysis is frequently used to examine trends in annual subscription growth. [4]

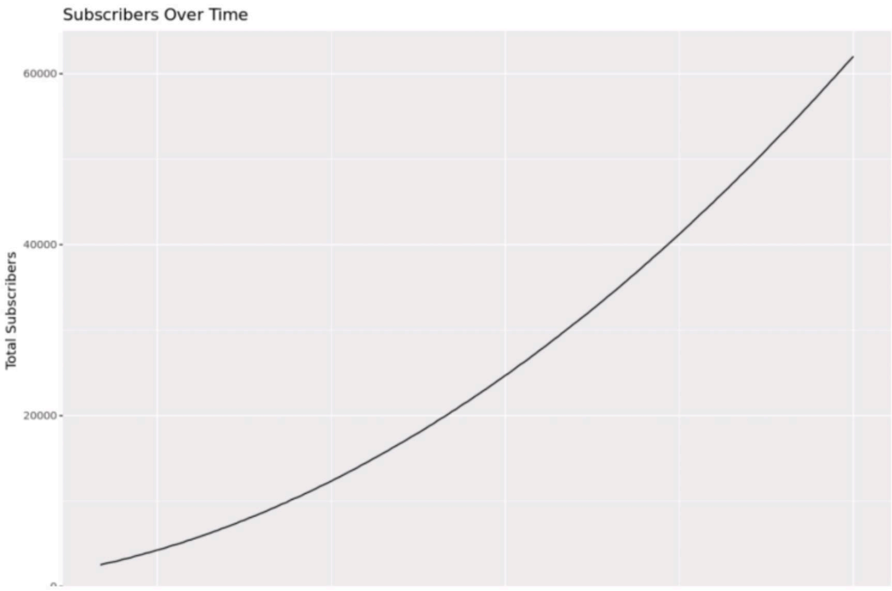


Figure 2.5: Subscribers over Time

2.4.1 Why organizations use time series data analysis

Utilising time series analysis, organisations may be better able to understand systemic patterns throughout time. Business users may use data visualisations to investigate seasonal trends and discover more about their causes. The analytics technologies available today allow these visualisations to do much more than merely show line graphs.

When analysing data on a regular basis, organisations may use time series forecasting to calculate the probability of future events. Time series data prediction is a component of predictive analytics. It can point out likely data changes, including seasonality or cyclical behaviour, which helps forecasting and provides a clearer understanding of data variables.

2.5 Understanding Time series Analysis

A time-indexed set of data points is referred to as time series data. Typically, this arrangement spans similarly spaced time periods like minutes, hours, days, months, or years. Time series data are distinguished from cross-sectional data, when observations are made at a particular moment in time, by their sequential character.

Effective modelling requires a thorough understanding of the distinctive properties of time series data:

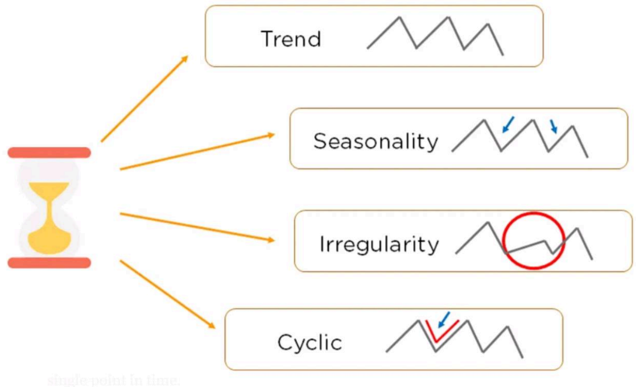


Figure 2.6: Properties of Time Series Analysis

- **Trend:** This indicates a sustained increase or decrease in the data. Trends can be linear or nonlinear.
- **Seasonality :** This phrase is used to refer to regular, predictable fluctuations in a time series that occur over a defined period of time, such as daily, monthly, or yearly fluctuations.
- **Cyclicity :** Cycles don't have a fixed duration as seasonality does. They describe data variations without a predetermined frequency.
- **Irregularity :** These data variations are illogical and random. After trends and seasonality are taken into consideration, there are frequently residuals or inaccuracies in the data.

2.6 Time Series Analysis and Forecast

Time is a crucial component that your model must take into consideration, whether you wish to forecast the evolution of financial markets or power usage. Predicting peak power use, for instance, might be interesting in order to change pricing and output. Bring on the time series. Simple data items grouped in chronological sequence make up a time series. Making predictions about the future is frequently the aim of time series, where time is frequently the independent variable. When working with time series, however, other factors are equally crucial.

Does it move around?
Is there a seasonal pattern?
The target variable has autocorrelation, right?

The many characteristics of time series and ways to model them for the most precise forecasts are listed below:

Autocorrelation The resemblance between observations as a function of their distance in time is known as autocorrelation.

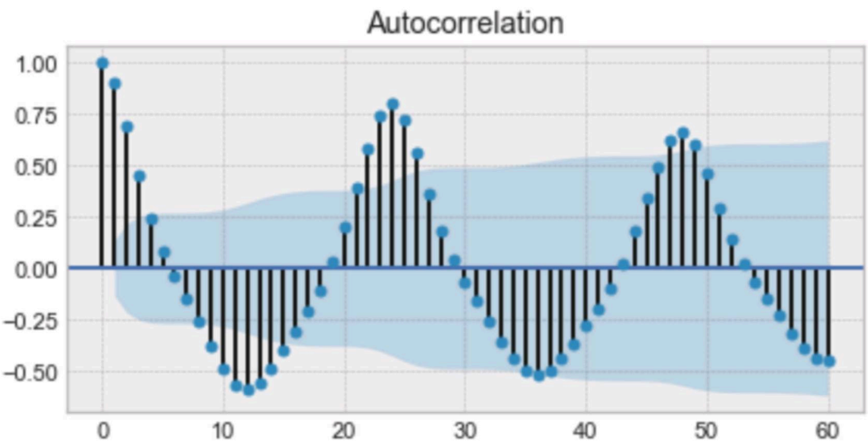


Figure 2.7: Example of Autocorrelation Plot

An autocorrelation plot is seen in the image above. The first value and the 24th value exhibit strong autocorrelation, as can be seen by paying great attention. The 12th and 36th observations also have a high correlation. This indicates that every 24 time units, values that are quite comparable are discovered.
The graph resembles a sine function, as you can see. Finding the time period (which corresponds to 24 hours) in the graph above will allow you to calculate this indicator of seasonality's value.

Seasonality Periodic change is referred to as seasonality. As an illustration, night-time electricity use is lower than during the day. In addition, during the Christmas season, internet sales rise before falling again.

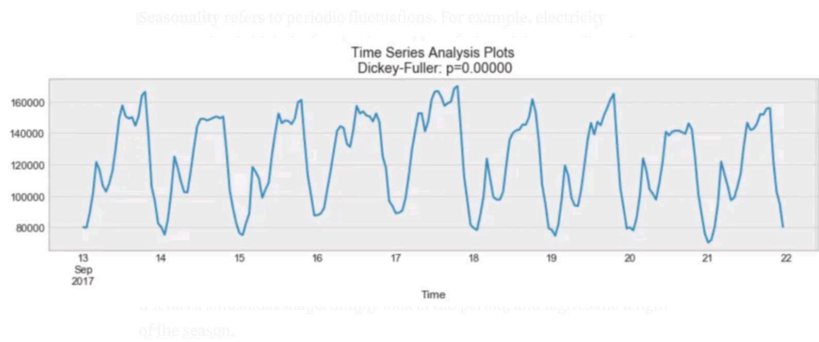


Figure 2.8: Example of Seasonality in Time Series Analysis Plot

As you can see from above, the daily seasonality is clear. Each day has a high in the evening and a low at the beginning and end of the day.

Note that if the autocorrelation plot is sinusoidal, the seasonality can also be derived from it. You can tell how long a season is just by looking at the period.

Stationarity Time series have stationarity as a crucial component. If the statistical characteristics of a time series remain constant across time, it is said to be stationary. In other words, the covariance is independent of time and the mean and variance are constant.

Figure 2.9: Example of Stationarity in Time Series Plot

We may observe that the aforementioned process is static by taking another look at the same diagram. Over time, neither the mean nor the variance change.

Due to growing tendencies that may be seen and rising volatility (i.e., shifting variation), stock prices are frequently not a steady-state process.

For modelling, we ideally require a stationary time series. Of course, not all of these are static, but you can change them in a number of ways to make them static.

Chapter 3

Data and Methodology

Cherrapunji has been chosen as the focus of our research. Within the Indian state of Meghalaya, the town of Cherrapunji is a subdivision. Despite repeated claims to the contrary, the adjacent Mawsynram region now holds the title of being the wettest spot on Earth. But it still holds the record for the highest precipitation in a month and a year: 9,300 millimetres (370 in; 30.5 ft) in July 1861 and 26,461 millimetres (1,041.8 in; 86.814 ft) between August 1, 1860, and July 31, 1861. [6]

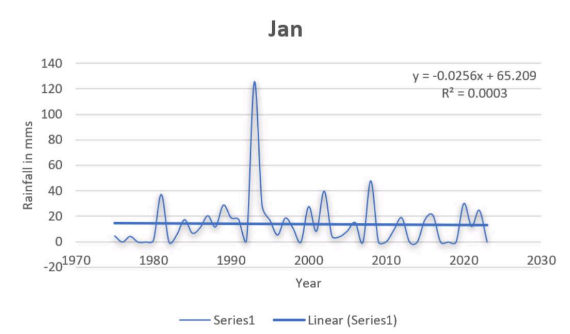
This station was chosen because it had more readily available data and it represented the area with the most rainfall records.
Data on the station's monthly rainfall is gathered. Table below displays specifics on the availability of monthly data. [3]

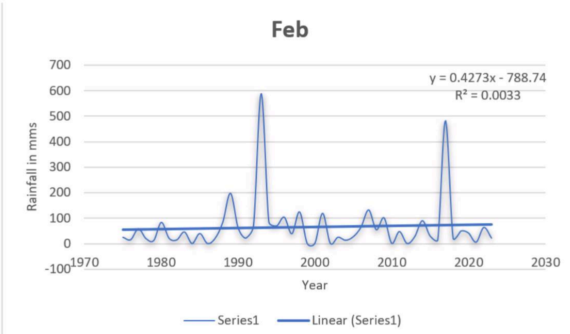
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
50 Year Average (1973 - 2022)	13.8	69.9	318	878.3	1306.4	2529.8	2921.9	1771.1	1192.7	505.1	52.4	19.7	11579.1
2023	0	21.3	299.8										321.1
2022	24.8	63	385.4	2008.9	2402.4	5343.4	892	565.2	758.9	589.1	0	10.4	13043.5
2021	12.2	5	160.8	342.6	811.3	2546.6	1211.7	2471.6	226.3	306	0	7.8	8101.9
2020	30.2	41	27.2	428.6	1866.1	3236.9	3811	1398.5	2438.5	687.1	29.2	0	13994.3
2019	0	48.8	40.1	360.3	1262.9	2196.2	2946.3	881.4	1184.4	655.2	25.4	4	9605
2018	0	21.2	114.2	342.1	981.8	1591.3	2053.6	1191.3	957	152.8	5.2	14.4	7424.9
2017	0	480.6	597.7	1884.8	569.6	2339.5	1948.2	2093	1252.1	807.8	17.6	51	12041.9
2016	21.1	14.4	128.8	2287.3	1239.6	1075.8	3913	502.7	741.1	472.7	28.2	11.6	10436.3
2015	17.7	29.4	33.4	616.2	1212.8	4355.5	1263.2	3097.3	1369.7	80	14.1	11	12100.3
2014	0	89.2	65.1	279.2	1456.6	2004.9	1848.3	2740.1	1725.4	27	0	0	10235.8
2013	0	26.8	7.4	471.4	1422.9	1525.7	1858.8	1098.6	610.2	538.5	0	0	7560.3
2012	19	0	175.2	1223	836.2	3445.2	3624.4	1283	2083.2	640.8	33.2	1	13364.2
2011	9.6	46.8	1514	226.3	710.4	1863.4	1369.2	1951.7	1010.8	30	0	0	8732.2
2010	0.2	1	808	2734.5	1337.8	3340.3	2158.3	1528.4	888.1	615.6	27.6	32.6	13472.4
2009	0	100.4	85.8	636.2	1003.2	1299.8	2513	2424.6	641.1	360.6	5.2	0	9069.9
2008	47.9	54	570.3	509.3	400.7	2092.6	3615.8	2966.4	789.3	368.3	0	0	11414.6
2007	0	131.4	21.6	800.3	1081.3	2601	4132.8	973.6	1958	728.4	218.4	0	12646.8
2006	15.3	63.8	336	844.1	1351.7	2523.8	3199.9	1839	1212.6	550.8	66.3	25.3	8734.1
2005	8.7	26.6	523.6	560.2	624.8	2204.7	2343.1	2662.2	314.3	489.8	0	0	9758
2004	4.2	12.6	1119.6	1334.9	1540.7	1670.5	5014.6	1472	1136.4	1457.3	Trace	28	14790.8
2003	4.7	24.4	163.2	501.5	897.9	3221.9	2927.1	1480.8	598.9	651	16.4	11	10498.8
2002	39.9	1.1	316.8	1285.2	1095.9	3893.4	3007	1306.6	947.4	69.1	298.6	1	12262
2001	8.4	118.2	27.8	679.6	547.1	2021.3	2519	1106.8	1373.2	542	28.1	0	8971.5
2000	27.8	1	190.8	1313.7	1762.9	3265.4	1639.7	2731.5	1040.3	275.1	14	0	12262.2
1999	0	0	211.8	1107.8	2152.1	2812.9	3094.9	2089.9	402.1	626.8	1	3.5	12502.8
1998	10.6	123.7	363.1	265.1	1481.3	4269.9	3686.6	3180.9	494.5	389	272.2	0	14536.9
1997	18.8	38.2	72.5	312.5	850.2	2489.7	2478.5	1364.3	1300.7	19.6	11.8	36.8	8993.6
1996	5.5	103	1095.2	805.3	2066.8	1753.8	4061.7	1559.1	316.1	1130.1	0	0	12896.6
1995	17.2	68.4	96.9	332.4	2324	4710.9	2515.2	2530.7	1208.6	54.8	350.7	0	14209.8
1994	28.4	84.7	1428.6	341.2	1723.3	3444.5	1538.8	1375.4	479.5	752	8.4	0	11204.8
1993	125.4	586.9	367.2	264	1222.3	3137.2	3067.4	2775	968.1	275.4	12.4	0	12801.3
1992	1.8	68.6	644.5	533.4	852.6	1919.3	2105.9	1019.4	1165.3	218.1	2.5	5.1	8356.5
1991	17.5	21	51.4	443.9	2756.8	2695.5	2724.1	1654.4	2356.6	693.5	2.6	88.6	13505.9
1990	19	60.9	155.3	1699.4	1183.1	2782.8	2394.7	974.2	1401.3	896	29.5	1.5	11597.7
1989	28.9	196.8	20.8	1670	1058.8	2601.5	4584.3	1079.2	1306.6	868.5	41.2	2.8	13460
1988	11.9	83.4	150.5	364.4	3536.6	2288.5	3820	4659.2	1735.5	876.7	291.7	112	17930.4
1987	20.6	20.2	322.2	792.5	652	3053.1	4446.1	1693.3	1944.2	118.5	36.5	54.1	13153.3
1986	11.1	0	53.8	1411.3	158.4	1429.3	1908.6	1344.2	1055.6	606.7	155	5.5	8139.5
1985	7	39.2	831.2	1040	1069.5	2708.2	3666.7	1634	764.1	32.4	2.3	21.7	11816.3
1984	17.5	0	136.7	871.3	3961.2	2259.8	5420.7	1069.8	2622.2	292.4	7	102.1	16760.7
1983	5.6	45.2	112.6	389.4	433.4	1315.2	3194.4	2102.7	1799	322.9	1.5	42.1	9764
1982	0	13.8	40.3	751	766.1	2258.2	2995.1	1882.2	1629.9	60	43	1.2	10380.8
1981	37.4	20.6	177.8	375.1	764.5	1578.3	3840.5	1406.1	1057	36.8	0	123.4	9417.5
1980	1.4	82.6	142.4	1092.2	1038.4	1472.3	2098	2079.6	587.6	538.4	0	0	9132.9
1979	0	11.4	109.4	324.6	1667.1	1346.8	4006.4	1179.5	1857.8	1478.4	55.4	58	12094.8
1978	0	19.2	72.7	196.5	900.4	2135.8	2133.8	623.4	602.4	222.4	43.7	0	6950.3
1977	4.4	57.6	656.8	1480.2	1868.6	2059	2127.4	2763.7	430.5	584.1	62.3	15.1	12109.7
1976	0	14.8	1200.2	586.2	474.4	2630.4	1624.9	2006.4	291.6	183.6	7	0	9019.4
1975	4.8	24.4	26.2	1470.6	1257	1673.8	4097.8	1240.9	1057.7	1108.2	0	0	11961.4

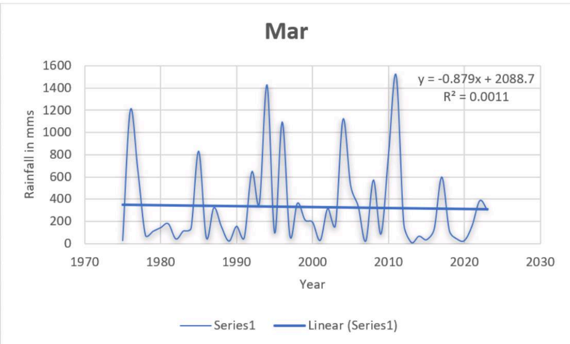
Table 3.1: Table displaying Monthly Rainfall data of Cherrapunji

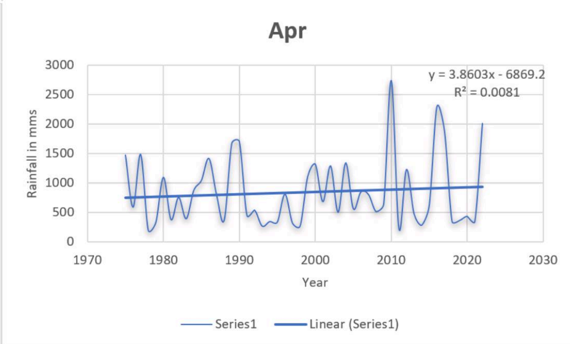
3.1 Monthly Analysis

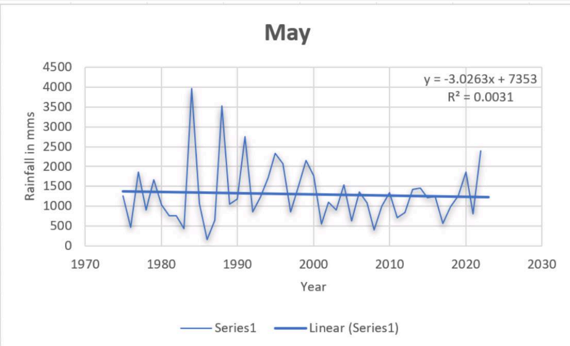
The graphs below show the monthly rainfall time series analysis of Cherrapunji over a time period of 48 years along with the **linear trendline**, **trendline equation** and **R-squared** value. The trendline equation is a formula for determining the line that best matches the given set of data points. R-squared value is a measure of the trendline reliability; the closer R2 is to 1, the more reliable the trendline is.

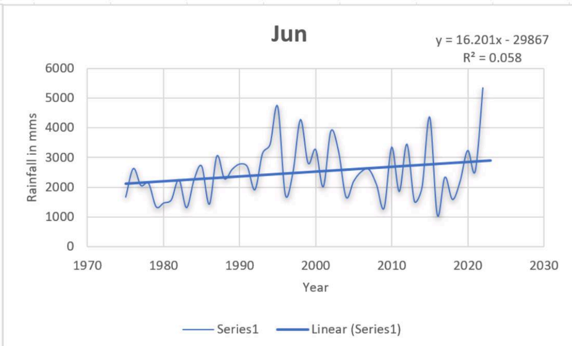


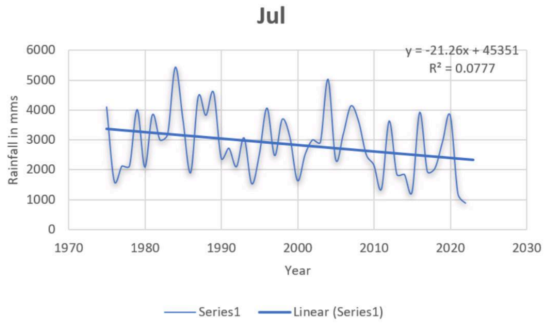


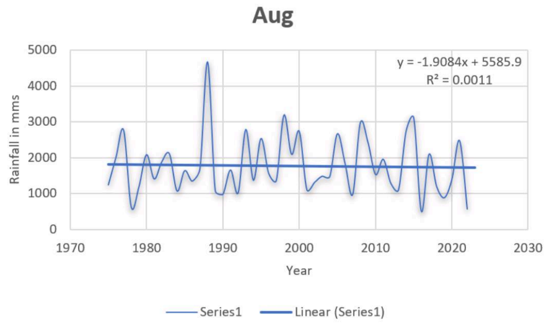


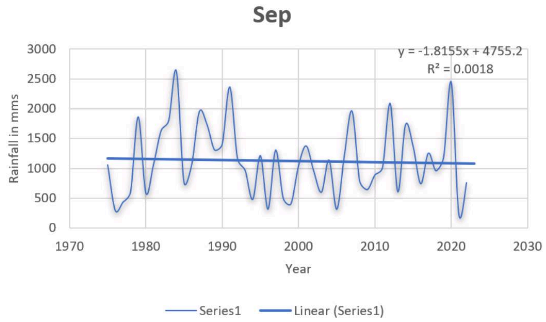


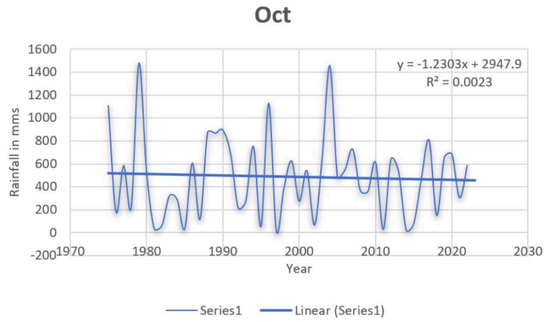


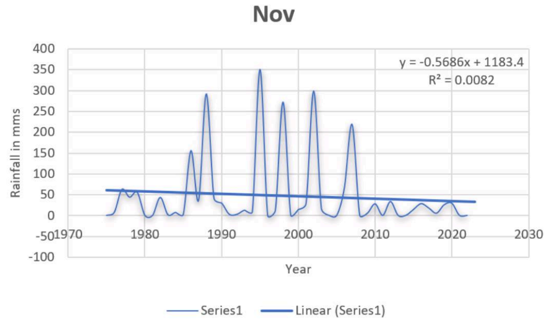


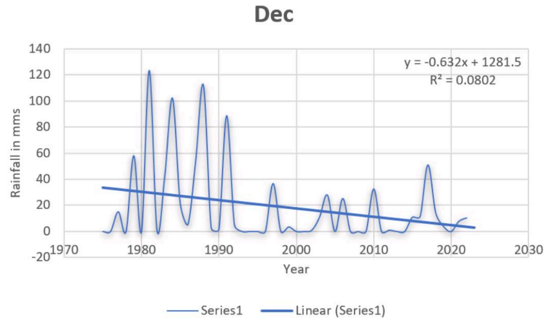

Jul
y = -21.26x + 45351
R² = 0.0777
Rainfall in mms
Year
Series1
Linear (Series1)

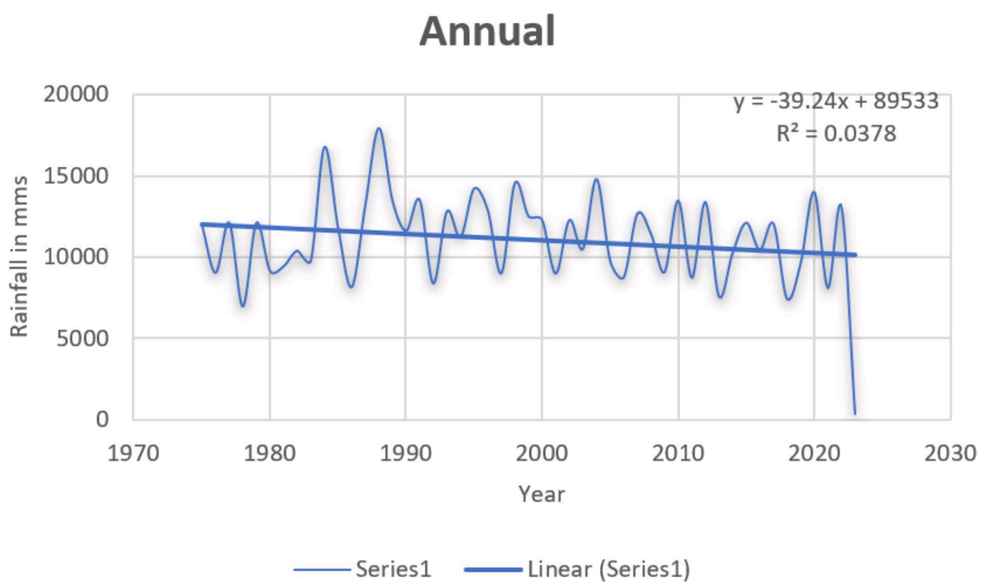

Aug
y = -1.9084x + 5585.9
R² = 0.0011
Rainfall in mms
Year
Series1
Linear (Series1)


Sep
y = -1.8155x + 4755.2
R² = 0.0018
Rainfall in mms
Year
Series1
Linear (Series1)


Oct
y = -1.2303x + 2947.9
R² = 0.0023
Rainfall in mms
Year
Series1
Linear (Series1)


Nov
y = -0.5686x + 1183.4
R² = 0.0082
Rainfall in mms
Year
Series1
Linear (Series1)


Dec
y = -0.632x + 1281.5
R² = 0.0802
Rainfall in mms
Year
Series1
Linear (Series1)


Annual
y = -39.24x + 89533
R² = 0.0378
Rainfall in mms
Year
Series1
Linear (Series1)

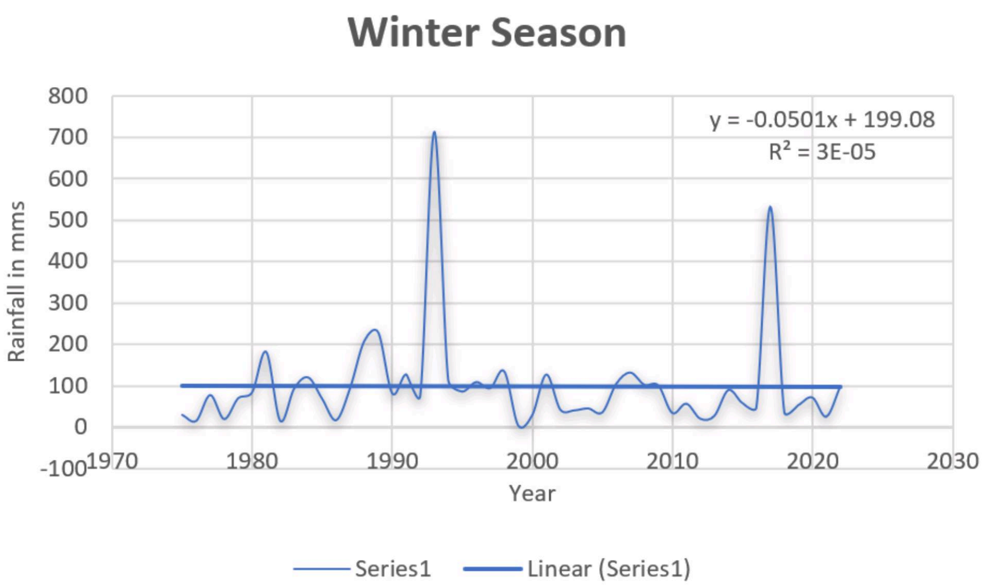
3.2 Seasonal Analysis

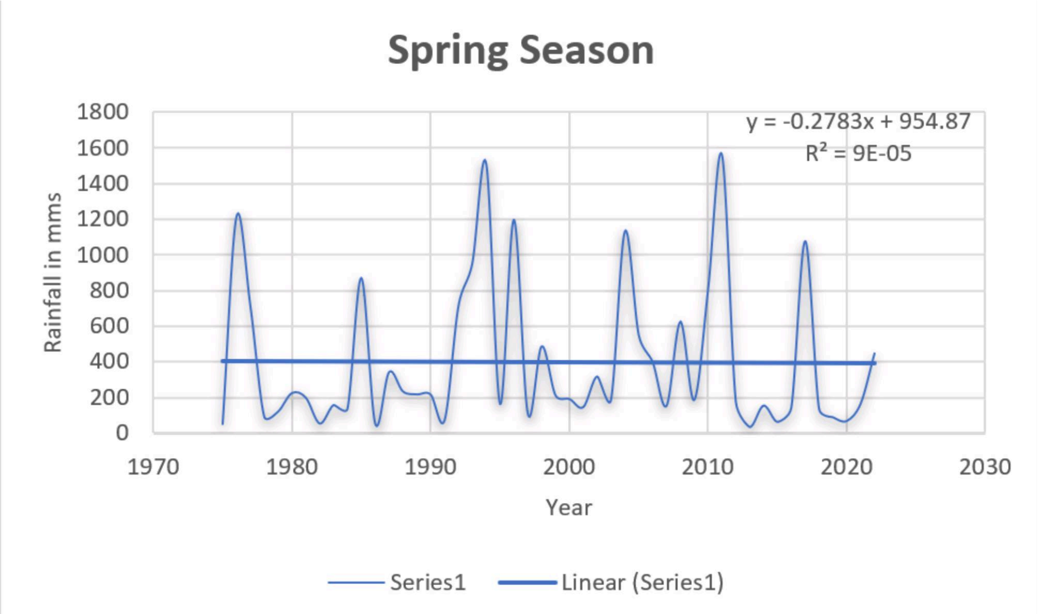
The weather conditions of the Cherrapunji remain pleasant and comfortable for most of the year. The town receives heavy rainfall throughout the year. Winters in Cherrapunji begin in December and end in January followed by Spring season in the months of February and March. Summer season remains in the months of April and May. The Monsoon season is the longest which begins in June and lasts till September. Autumn season lasts from October and November. Table 3.2 shows the data broken down into these five seasons.

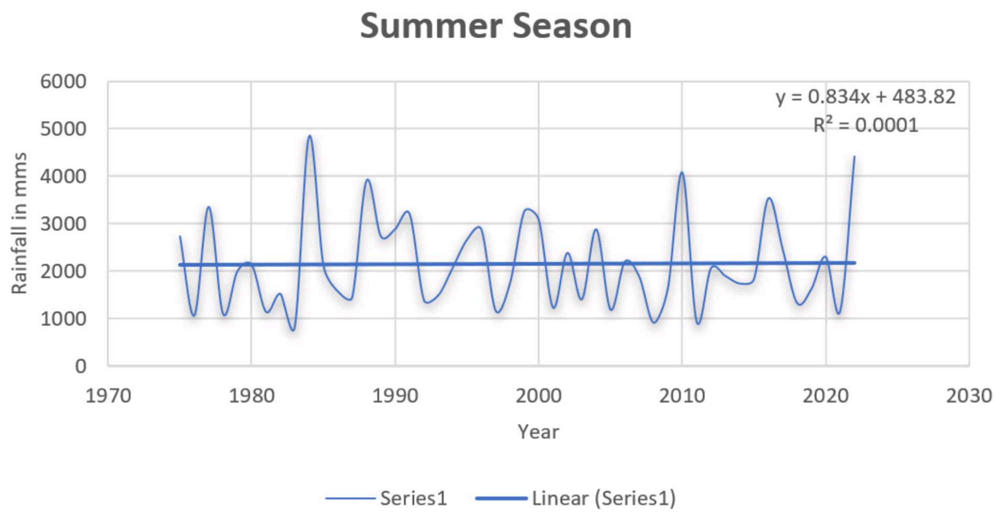
Year	Winter	Summer(Pre-Monsoon)	Spring	Monsoon	Autumn(Post-Monsoon)
	Dec-Jan	Apr-May	Feb-Mar	June-Sep	Oct-Nov
2022	98.2	4411.3	448.4	7559.5	589.1
2021	25	1153.9	165.8	6456.2	306
2020	71.2	2294.7	68.2	10884.9	716.3
2019	52.8	1623.2	88.9	7208.3	680.6
2018	35.6	1323.9	135.4	5793.2	158
2017	531.6	2454.4	1078.3	7632.8	825.4
2016	47.1	3526.9	143.2	6232.6	500.9
2015	58.1	1829	62.8	10085.7	94.1
2014	89.2	1735.8	154.3	8318.7	27
2013	26.8	1894.3	34.2	5093.3	538.5
2012	20	2059.2	175.2	10435.8	674
2011	56.4	936.7	1560.8	6195.1	30
2010	33.8	4072.3	809	7915.1	643.2

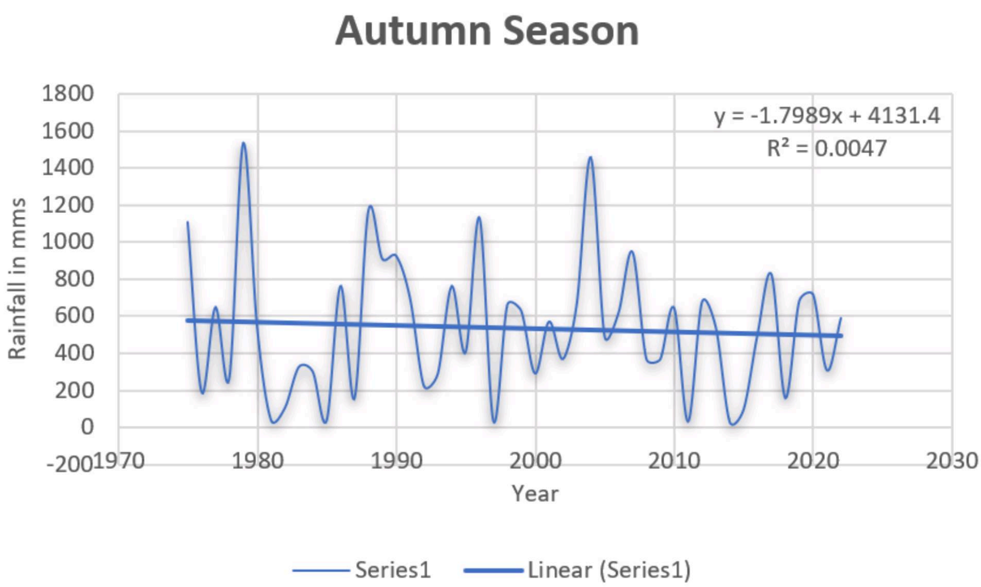
2009	100.4	1639.4	186.2	6878.5	365.8
2008	101.9	910	624.3	9464.1	368.3
2007	131.4	1881.6	153	9665.4	946.8
2006	104.4	2195.8	399.8	8775.3	617.1
2005	35.3	1185	550.2	7524.3	489.8
2004	44.8	2875.6	1132.2	9293.5	1457.3
2003	40.1	1399.4	187.6	8228.7	667.4
2002	42	2381.1	317.9	9154.4	367.7
2001	126.6	1226.7	146	7020.3	570.1
2000	28.8	3076.6	191.8	8676.9	289.1
1999	3.5	3259.9	211.8	8399.8	627.8
1998	134.3	1746.4	486.8	11631.9	661.2
1997	93.8	1162.7	110.7	7633.2	31.4
1996	108.5	2872.1	1198.2	7690.7	1130.1
1995	85.6	2656.4	165.3	10965.4	405.5
1994	113.1	2064.5	1513.3	6838.2	760.4
1993	712.3	1486.3	954.1	9947.7	287.8
1992	75.5	1386	713.1	6209.9	220.6
1991	127.1	3200.7	72.4	9430.6	696.1
1990	81.4	2882.5	216.2	7553	925.5
1989	228.5	2728.8	217.6	9571.6	909.7
1988	207.3	3901	233.9	12503.2	1168.4
1987	94.9	1444.5	342.4	11136.7	155
1986	16.6	1569.7	53.8	5737.7	761.7
1985	67.9	2109.5	870.4	8773	34.7
1984	119.6	4832.5	136.7	11372.5	299.4
1983	92.9	822.8	157.8	8411.3	324.4
1982	15	1517.1	54.1	8765.4	103
1981	181.4	1139.6	198.4	7881.9	36.8
1980	84	2130.6	225	6237.5	538.4
1979	69.4	1991.7	120.8	8390.5	1533.8
1978	19.2	1096.9	91.9	5495.4	266.1
1977	77.1	3348.8	714.4	7380.6	646.4
1976	14.8	1060.6	1215	6553.3	190.6
1975	29.2	2727.6	50.6	8070.2	1108.2

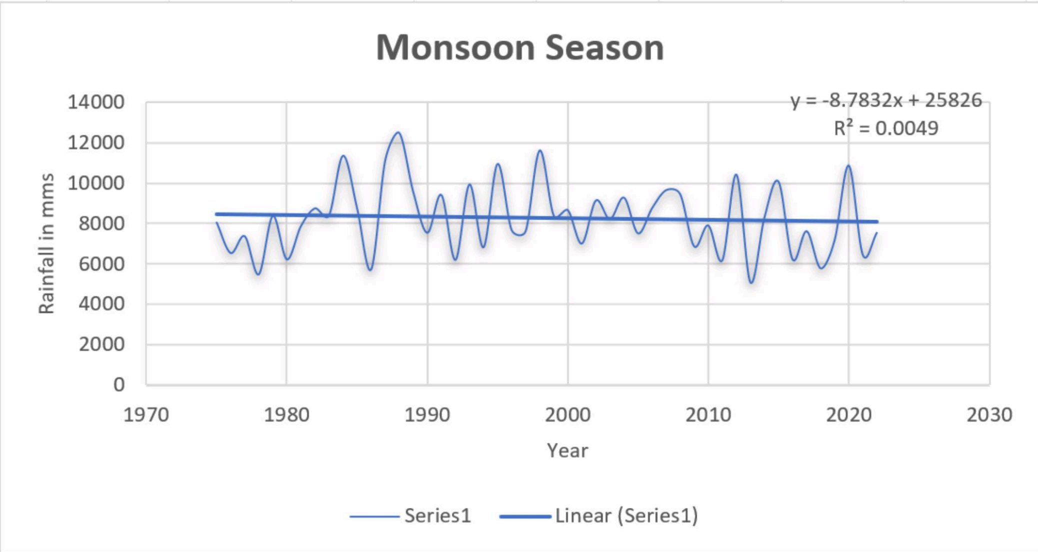
Table 3.2: Table displaying Seasonal Rainfall data of Cherrapunji


Winter Season
Rainfall in mms
Year
y = -0.0501x + 199.08
R² = 3E-05
800
700
600
500
400
300
200
100
0
-100
1970
1980
1990
2000
2010
2020
2030
Series1
Linear (Series1)


Spring Season
Rainfall in mms
Year
y = -0.2783x + 954.87
R² = 9E-05
1800
1600
1400
1200
1000
800
600
400
200
0
1970
1980
1990
2000
2010
2020
2030
Series1
Linear (Series1)


Summer Season
y = 0.834x + 483.82
R² = 0.0001
6000
5000
4000
3000
2000
1000
0
Rainfall in mms
1970
1980
1990
2000
2010
2020
2030
Year
Series1
Linear (Series1)


Autumn Season
y = -1.7989x + 4131.4
R² = 0.0047
1800
1600
1400
1200
1000
800
600
400
200
0
-200
Rainfall in mms
1970
1980
1990
2000
2010
2020
2030
Year
Series1
Linear (Series1)


Monsoon Season
y = -8.7832x + 25826
R² = 0.0049
14000
12000
10000
8000
6000
4000
2000
0
Rainfall in mms
1970
1980
1990
2000
2010
2020
2030
Year
Series1
Linear (Series1)

Chapter 4

Discussion

4.1 Trend Analysis

4.1.1 Monthly analysis

Observing the graphs, we conclude that the highest value of R-squared is 0.082 that is December. Hence, the trendline of December is the most reliable amongst the other months, followed by July (0.077) and June (0.058). The January trendline is the least reliable with R-squared value of 0.0003.

The rainfall trend in the months January to May remained almost constant over the years with a very slight rise in the Month of April. We can see a little hike in the rainfall between the years 1990-2000 in the months of January, February and March. The highest recorded rainfall in the month of January and February is 125.4 mm and 586.9 mm respectively in the year 1993. March has the highest recorded rainfall of 1514 mm in the year 2011. The June trendline has a positive slope which indicates a little rise in the rainfall trend over these years with the highest recorded rainfall(5343.4 mm) in the year 2022 whereas July has a negative slope indicating a fall in the rainfall over the years with the highest recorded rainfall(5420.7 mm) in 1984. Moving further, the trends of months of August to November have very slight or no variation over the years. We can see a visible variation in the month of December, the trendline of which has a negative slope with a highest rainfall of 123.4 mm in the year 1981 and a lowest rainfall of 0 mm. The average rainfall fell from 33.72 in the years 1975-1990 to 10.72 in the years 1991-2022.

We can see a very slight fall in the rainfall trend over the years annually. The highest annual rainfall recorded is 17931.4 in the year 1988 while the lowest annual rainfall recorded is 6950.3 in the year 1978.

4.1.2 Seasonal Analysis

The average rainfall of the 48 years in winter season is 99.05mm which is the least amongst all the other seasons. Cherrapunji experienced most rainfall in its monsoon season with an average of 8272.37mm that lasts from June to September with the highest rainfall of 12503.2mm recorded in the year 1988 and the lowest rainfall of 5093.3mm recorded in the year 2013. The spring season recorded its average rainfall as 398.713mm with the rainfall trend being constant. The pre-monsoon or the summer season recorded the most rainfall after the monsoon season with an average of 2150.54mm. The average rainfall in the post-monsoon or autumn season was found to be 536.365mm. We can see a slightly falling trendline which indicates the fall in the rainfall over the years in this season.

4.2 Causes of rainfall variation

Large regions of India get moderate to heavy amounts of convective precipitation, but there have also been periods of low convective rainfall, which have delivered sufficient moisture from the Indian Ocean to land areas, making rainfall production unfavourable. Due to this, the extreme southern and mid-central regions of the nation experienced a drop in the mean amount of rainfall during the monsoon season. The northeasterly wind was intensified over the whole nation, which decreased the intrusions of colder air and resulted in a decrease in rainfall throughout India in the winter. In contrast, the majority of the divisions saw moderate to high mean convective precipitation rates, which to some degree boosted rainfall. All throughout India, low clouds have grown, and a few of them will boost the atmosphere's ability to concentrate solar radiation, which will result in a downward trend in rainfall. In addition, the nation as a whole, with the exception of the eastern division, has seen high mean total precipitation rates that have caused irregular downdraft patterns and increased the number of clear sky days in recent years (1979–2017). A large decrease in rainfall caused a diminishing vertically integrated moisture differential in the majority of Indian areas.

The Bay of Bengal branch of the Indian summer monsoon brings rain to Cherrapunji. About 400 km of Bangladesh's plains are unobstructed by the monsoon clouds as they pass overhead. The Khasi Hills, which climb suddenly from the lowlands to a height of around 1,370 m above mean sea level within 2 to 5 km, are the next obstacle they encounter. The low-flying (150–300 m) moisture-laden clouds from a large area converge over Cherrapunji due to the topography of the hills, which has numerous deep valley channels. The winds force the rain clouds up the steep slopes and through these valleys. The quick climb of the clouds into the higher atmosphere speeds up cooling and aids in the condensing of vapours. The majority of the rain is produced when a massive body of water vapour lifts air. The most well-known characteristic of orographic rain in northeastern India is arguably the high amount of rainfall.

On occasion, Cherrapunji will see cloudbursts in one location while remaining completely or largely dry in other parts, which is a reflection of the considerable spatial variability of rainfall. In the height of the monsoon, there is an extraordinarily high level of atmospheric humidity.

The majority of the monsoon rain in Cherrapunji occurs in the morning, which is a unique characteristic. This may be partially caused by the convergence of two air masses. The Brahmaputra valley experiences predominant winds that often come from the east or northeast during the monsoon season, although Meghalaya experiences winds that come from the south. The Khasi Hills are often where these two wind systems converge. It seems that only after being warmed during the day do the winds that are locked in the valley at night start to ascend. This helps to explain how often it rains in the morning. The hourly analysis will be able to investigate this more in the future.

Chapter 5

Conclusion & Future Scope

A strong statistical technique for examining and predicting temporal data is time series analysis. The important insights from the time series data make better educated decisions if one has a thorough grasp of the fundamental ideas and methods used in time series modelling, such as decomposition, stationarity, autocorrelation, and different forecasting models. To study the trend of monthly and seasonal rainfall, Cherrapunji has been selected. Data is collected and time series analysis is carried out by plotting graphs month wise and season wise. The linear trendline is plotted along with R-squared value and compared. The data is missing for two months, which is one of the study's shortcomings. If the missing data could be located, the analysis's quality might be raised. It is significant to remember that the monsoon season sees the maximum rainfall at Cherrapunji. As far as future scope is concerned, forecasting can be incorporated into the study's domain after analysis.

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