A Project Report on

Does the Variance of Daily Rainfall During the Monsoon in West Bengal Change: An Evidence from a Statistical Hypothesis Testing

A Dissertation Submitted to

Department of Statistics
University of Kalyani
Kalyani, Nadia, West Bengal - 741235, India

in partial fulfillment of the requirements for the Degree of
Master of Science (5-Year Integrated) in Statistics

by
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CANDIDATE'S DECLARATION

I, Anirban Ghosh, Roll 96/STS No. 190004, Registration No. 100620 of 2019 - 2020, hereby declare that the project report titled "Does the Variance of Daily Rainfall During the Monsoon in West Bengal Change: An Evidence from a Statistical Hypothesis Testing" submitted in partial fulfilment for the award of the Degree of Master of Science (5-Year Integrated) in Statistics at Department of Statistics, University of Kalyani is an original piece of project work carried out by our group of three students - Anirban Ghosh, Dipanta Mistry and Achyut Ghosh under the guidance and supervision of Dr. Raju Maiti Sir of Economic Research Unit, Indian Statistical Institute, Kolkata. We further declare that the information presented in this project report has been collected from genuine and authentic sources and this project report is not submitted for the award of any Degree, Diploma and Fellowship or like other similar title or recognition.

We acknowledge that any external sources and contributions utilized in this project report have been duly cited and credited.

Date: 06.08.2024

Place: Kalyani

Anirban Ghosh .

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CERTIFICATE

This is hereby certified that Anirban Ghosh, Dipanta Mistry and Achyut Ghosh, a group of three M.Sc. (5-Year Integrated) students of Department of Statistics, University of Kalyani have carried out a project work titled "Does the Variance of Daily Rainfall During the Monsoon in West Bengal Change: An Evidence from a Statistical Hypothesis Testing" under my supervision in partial fulfillment of requirements for the degree of Master of Science (5-Year Integrated) in Statistics. The work done in this project is the result of the candidates' own effort and has not been submitted elsewhere for the award of degree/diploma in any other Institute/University. The project work has been carried out from December 2023 to August 2024.

Date: 06.08.2024

Place: Kolkata

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Place: Kalyani

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Last but not the least I would like to express my sincere gratitude to Department of Statistics, University of Kalyani for providing me such great opportunity to pursue the prestigious course.

ABSTRACT

Objective: The aim of this study is to analyze the daily rainfall in six districts of West Bengal to study if there is any change in consistency of Monsoon rainfall over time. This will help to find any change in distribution of rainfall over years. Another purpose of this study is to forecast Monsoon rainfall of upcoming years based on past rainfall data.
Methods: We employ Regression analysis technique to detect trend in the Monsoon variance. Apart from Regression analysis, we also consider a non-parametric approach by performing Mann-Kendall Test to detect trend in Monsoon variance. Then we fit ARIMA model to forecast rainfall in Monsoon for next 10 years.
Results: The variance of Monsoon rainfall shows a significantly increasing trend for the districts Manbhum Purulia and South 24 Parganas. It shows a significantly decreasing trend for Darjeeling. For Nadia, Monsoon variance is stable over 120 years and no proper conclusion can be made for Coochbehar and Malda.
Conclusion: There is an indication that distribution of Monsoon rainfall has been changed in some certain regions of West Bengal. More detailed study can reveal more aspects of change in distribution of Monsoon rainfall in West Bengal.

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1 Introduction

Agricultural prosperity of any state in India heavily depends on timely and adequately distributed rainfall, especially during Monsoon season. However, Monsoon rainfall may vary heavily across regions and on temporal scales. For example, some states may witness a delay and dry conditions in the Monsoon, and other states may face extreme rainfall, resulting in floods and heavy landslides, affecting the normal livelihoods and agricultural production. Therefore, it is imperative to understand the time series trend and variability of the Monsoon rainfall over the years. In this paper, we consider the daily rainfall of different districts of West Bengal. West Bengal is the highest rice production state of India and commands the lion's share of India's rice production, contributing a substantial 14% to the nation's overall output [1]. It spreads across six climatic zones, starting from the Bay of Bengal to the norther hill district of Darjeeling. It is constituted in the heart of fertile geographical delta and thus, comprises of a high geographical diversity with six agro-climatic zones. Rice yield, in particular in West Bengal, heavily depends on the timely and adequately distributed Monsoon rainfall. Irregular rainfall pattern causes a great impact on annual food-grain production including wet season rice. Therefore, understanding the trend and the variability of rainfall during the Monsoon season is the main purpose of this study.

According to the Indian Meteorological Department (IMD), a Monsoon season, starting from 1st June to 30 September, is declared to be normal if the total rainfall across all the states in the country is near to the average rainfall [2] which is 1176.32 mm [13]. While declaring a Monsoon season to be normal, IMD considers only at the country level total rainfall during Monsoon period. However, in reality, different states and different regions may experience heavy rain or no rain at the same time, resulting in affecting agriculture production at local level. If this phenomenon persists for year after year, new policies should be introduced at the local or district level.

Various attempts have been made to study characteristics of rainfall in different places. Most of the studies deal with trends and variations of rainfall. Besides pattern of average rainfall, study of variation is also necessary to clearly understand the characteristic of rainfall. In many situations, variance becomes correlated with total rainfall. So apart from variance, other measures of variation may also be helpful.

Halder et al. [11] assessed long-period (1901-2020) trends and magnitude of seasonal and annual rainfall across districts of West Bengal and observed that both the annual and seasonal rainfall increased non-significantly except for Winter, which experienced a non-significant decrease. Guhathakurta et al. [10] studied the result of the analysis based on 30 years (1989-2018) of data on the mean spatial rainfall pattern as well as mean spatial pattern of different rainfall events, trends and variability as well as extreme rainfall events during the Monsoon months and annual for West Bengal. Datta and Das [7] showed that the presence of autocorrelation increases trend in a time series and inspected dynamics of precipitation using the original MK test along with three modified version in West Bengal. Kundu and Mondal [15] analyzed long-term annual and seasonal rainfall trends along with change point of annual rainfall using 102 years (1901-2002) monthly rainfall data of 18 rainfall stations in West Bengal and observed 1952, 1956 and 1967 as most likely change points for different regions within West Bengal. Ghosh [8] studied long-term spatial and temporal trends of rainfall at monthly, seasonal and annual scales for 12 meteorological stations of Gangetic West Bengal (GWB) using 102 years (1901-2002) of rainfall data and suggested that the Monsoon is being delayed on its onset and withdrawal. Bardhan [5] measured seasonality of rainfall of the districts of West Bengal by an index of seasonaliy as derived by Walsh and Lawler [20]. Chatterjee et al. [6] investigated spatio-temporal monotonic trend and shift in concentration of Monsoon precipitation across West Bengal by analysing the time series of monthly precipitation from 18 weather stations during the period from 1901-2002. Mukhopadhyay et al. [17] obsereved maximum number of districts in West Bengal showed increasing trend in rainfall both annully and in Monsoon months and a slight change for non-Monsoon months.

The rest of the paper is presented as follows. In Section 2, we describe the aggregation and pre-processing of the dataset, including missing value replacement. In Section 3, we describe the methods used to measure trend in Monsoon variance over 120 years and to forecast Monsoon rainfall. Section 4 gives ideas about rainfall characteristics in various districts of West Bengal through some exploratory data analysis and visualization.The results of measuring trend of variances and forecasts of Monsoon rainfall are presented in Section 5. Section 6 concludes the report with discussions and future scope.

2 The Dataset

The present study examines daily rainfall data spanning 120 years (1901-2020) for West Bengal, India. The dataset comprises observations from multiple rain-gauge stations situated across various districts of West Bengal. Each station records daily rainfall, and these station-wise daily data are collected from West Bengal Pollution Control Board.

To facilitate state-level analysis, the station-wise data were aggregated using the following method. Suppose there are m stations in the whole state that record the rainfall as $y_{1t}, y_{2t}, \cdots, y_{mt}$ respectively on day t. To compute the state-level rainfall at day t, we take the average

$$y_t = \frac{1}{m}\sum_{i=1}^{m} y_{it}$$

and store it as the total rainfall on that day for the whole state. Similarly, if we want to compute the monthly rainfall of the state based on the daily rainfall collected from m stations, take the total rainfall from all the m stations during the whole month period and divide it by m. That gives us the monthly rainfall of the state. Similar way, we computed the Monsoon and annual rainfall of the state.

The dataset contains two types of missing values. Firstly, for certain districts, some monthly data are missing for specific years. These missing values were imputed using the average of the corresponding months from the preceding and following ten years. Secondly, for some districts, entire years of data are missing. These gaps were filled by averaging the data from the previous and next ten years for each respective date.

Our analysis primarily focuses on the monthly and seasonal rainfall patterns across West Bengal districts, with a particular emphasis on Monsoon rainfall. We aim to detect any shifts in Monsoon onset over the past twenty years and to examine changes in rainfall variability. An increase in Monsoon variability could indicate greater inconsistency in rainfall patterns, which can be quantified by the ratio of heavy rainy days to non-rainy days. For illustrative purposes, one district from each of West Bengal's six agro-climatic zones were selected: Darjeeling (Northern Hill Zone), Coochbehar (Terai-Teesta Alluvial Zone), Maldah (Vindhyan Alluvial Zone), Nadia (Gangetic Alluvial Zone), Purulia (Undulating Red Zone), and South 24 Parganas (Coastal Saline Zone) [3].

According to the India Meteorological Department (IMD) [12], the year is divided into four seasons: Pre-Monsoon (March-May), Monsoon (June-September), Post-Monsoon (October-November), and Winter (December-February). Rainfall intensities are categorized into four classes: No Rain (0-2.5 mm), Light Rain (2.5-15.5 mm), Moderate Rain (15.5-64.5 mm), and Heavy Rain (more than 64.5 mm) based on daily measurements.

Implementation of all the methods in this project is done in R, an open software with version 4.4.1. All the R codes of this project can be freely accessed from the author's GitHub repository of this project [4].

3 Methodology

3.1 Computation of Marginal Variance

Let Y_t represent the daily rainfall for a specific area or city. The year is divided into four distinct seasons: (i) Pre-Monsoon, (ii) Monsoon, (iii) Post-Monsoon, and (iv) Winter. The Pre-Monsoon season encompasses the months of March, April, and May. The Monsoon season includes June, July, August, and September. The Post-Monsoon season consists of October and November, while the Winter season spans December, January, and February.

For each year, we calculate the marginal variance using the daily values of Y_t during the Monsoon season. The marginal variance provides a measure of the variability in Y_t over the Monsoon period, offering insights into changes in rainfall or air quality consistency year over year. The formula for calculating the marginal variance is as follows:

$$MV_i = \tfrac{1}{T} \textstyle\sum_{t \in S_i} (Y_t - \bar{Y})^2$$

where S_i denotes the set of all days within the Monsoon season for year i, T is the total number of days in the Monsoon season, and $\bar{Y}$ is the mean value of Y_t over the Monsoon season for that year.

To elaborate on the calculation process, we first identify the days within the Monsoon season for each year i. Specifically, this involves determining the days t that fall between June 1st and September 30th, resulting in the set S_i. Next, we compute the mean value, $\bar{Y}$, of Y_t for all $t \in S_i$. This is achieved by summing all the daily values within the Monsoon period and dividing by the total number of days, T, in the season:

$$\bar{Y} = \frac{1}{T} \sum_{t \in S_i} Y_t$$

Subsequently, we calculate the marginal variance, MV_i, for each year. This involves computing the squared differences between each daily value Y_t and the mean value $\bar{Y}$, summing these squared differences, and then dividing by T to obtain the variance:

$$MV_i = \frac{1}{T} \sum_{t \in S_i} (Y_t - \bar{Y})^2$$

The resulting value, MV_i, represents the Monsoon variance for year i. By plotting MV_i against the corresponding years i, we can discern trends and variations in the consistency of Monsoon rainfall over time.

3.2 Testing Linear Regression Coefficient

Once we have computed the Monsoon variance for all years, we aim to fit a linear regression model of MV_i on i, which is expressed as:

$$MV_i = \alpha + \beta i + \varepsilon_i$$

where MV_i represents the Monsoon variance for year i, α is the intercept, β is the slope coefficient indicating the trend over time, and ε_i is the error term.

The estimated coefficients $\hat{\alpha}$ and $\hat{\beta}$ are obtained using the least squares method. The estimators are given by:

$$\hat{\beta} = \frac{\sum_{i=1}^{n} (i - \bar{i})(MV_i - \overline{MV})}{\sum_{i=1}^{n} (i - \bar{i})^2}$$

$$\hat{\alpha} = \overline{MV} - \hat{\beta}\bar{i}$$

where $\overline{MV}$ is the mean of MV_i and $\bar{i}$ is the mean of the years i.

Under the assumption that the error terms ε_i are normally distributed, the distribution of the estimated coefficient $\hat{\beta}$ is also normal with the following properties:

$$\hat{\beta} \sim N\left(\beta, \frac{\sigma^2}{\sum(i-\bar{i})^2}\right)$$

where σ^2 is the variance of the error terms, and $\sum(i-\bar{i})^2$ represents the sum of the squared deviations of the years from their mean.

The mean and variance of the estimated regression coefficient $\hat{\beta}$ are given by:

$$E(\hat{\beta}) = \beta$$

$$\text{Var}(\hat{\beta}) = \frac{\sigma^2}{\sum(i-\bar{i})^2}$$

The standard error of the estimated regression coefficient $\hat{\beta}$ is calculated as:

$$SE(\hat{\beta}) = \sqrt{\frac{\sigma^2}{\sum(i-\bar{i})^2}}$$

To test the significance of the regression coefficient β, we formulate the following hypotheses:

$$H_0 : \beta = 0 \quad \text{(Null Hypothesis: No trend in Monsoon variance over years)}$$

$$H_1 : \beta \neq 0 \quad \text{(Alternative Hypothesis: Significant trend in Monsoon variance over years)}$$

To test the null hypothesis $H_0 : \beta = 0$, we use the test statistic:

$$t = \frac{\hat{\beta}}{SE(\hat{\beta})}$$

where $SE(\hat{\beta})$ is the standard error of the estimated coefficient $\hat{\beta}$. Here σ^2 is estimated using the mean squared error. The test statistic t follows a t-distribution with $n-2$ degrees of freedom, where n is the number of observations (years).

The p-value for testing H_0 against H_1 is calculated as:

$$\text{p-value} = P(|t_{n-2}| > |t|)$$

The rejection region for the test, at a significance level α, is defined by the critical value $t_{\frac{\alpha}{2},n-2}$ from the t-distribution:

$$\text{Reject } H_0 \text{ if } |t| > t_{\frac{\alpha}{2},n-2}$$

By calculating the p-value and comparing it to the significance level, we can determine whether to reject the null hypothesis. If the p-value is less than α, we reject H_0, indicating that there is a significant trend in Monsoon variance over the years.

3.3 Mann-Kendall Test

The Mann-Kendall test (Mann [16] and Kendall [14]) uses relative magnitudes of the data to calculate trend. It is calculated from the sum of the sign of the slopes. The statistic S is

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k)$$

where
n = number of data point and
x_i = the i^{th} observation.

The $sgn(x_j - x_k)$ is an indicator function which takes on values 1, 0 or -1 according to the sign of $(x_j - x_k)$:

$$sgn(x_j - x_k) = \begin{cases} 1 & \text{if} \quad (x_j - x_k) > 0 \\ 0 & \text{if} \quad (x_j - x_k) = 0 \\ -1 & \text{if} \quad (x_j - x_k) < 0 \end{cases}$$

When n is large enough, under null hypothesis of no trend, S is normally distributed with

$$E(S) = 0 \text{ and } Var(S) = \frac{n(n-1)(2n+5) - \sum_{j=1}^{p} t_j(t_j-1)(2t_j+5)}{18},$$

where
p = number of tied groups in the dataset and
t_j is the number of data points in the j^{th} tied group.

Then S and Var(S) are used to compute the test statistic Z, which is computed as:

$$Z = \begin{cases} \frac{S-1}{\{Var(S)\}^{1/2}} & \text{if} \quad S > 0 \\ 0 \quad \text{if} \quad S = 0 \\ \frac{S+1}{\{Var(S)\}^{1/2}} & \text{if} \quad S < 0 \end{cases}$$

Under the null hypothesis of no trend, Z has a Standard Normal distribution. The trend is said to be decreasing if Z is negative and increasing if Z is positive. H_0, the null hypothesis of no trend, is rejected if the absolute value of Z is greater than $Z_{1-\frac{\alpha}{2}}$, where $Z_{1-\frac{\alpha}{2}}$ is obtained from the standard normal cumulative distribution tables.

3.4 Theil-Sen Slope Estimator

Theil-Sen slope estimtor (TSSE) (Theil [19] and Sen [18]) is not greatly affected by gross data errors or outliers and even it can be computed when data are missing (Gilbert [9]). The slope estimates of all data pairs is computed as:

$$Q_i = \frac{x_j - x_k}{j-k} \text{ for i = 1, 2, ..., N; (j > k)}$$

where
Q_i = slope between data points x_j and x_k,
x_j = data measurement at time j,
x_k = data measurement at time k,
N = number of data pairs.

The median of these N values of Q_i is Sen's estimator of slope. If there is only one datum in each period, then N = $\frac{n(n-1)}{2}$, where n is the number of period. If there are multiple observations in one or more period, then N ¡ $\frac{n(n-1)}{2}$, where n is the total number of observations not the number of period. The N values of Q_i are ranked from smallest to largest and the median of slope or Sen's slope estimator is computed as follows:

$$Q_{med} = \begin{cases} Q_{[\frac{N+1}{2}]} & \text{if N is odd} \\ \frac{Q_{[\frac{N}{2}]} + Q_{[\frac{N}{2}+1]}}{2} & \text{if N is even} \end{cases}.$$

The sign of Q_{med} reflects data trend reflection, while its value indicates the steepness of the trend.

3.5 Forecasting with ARIMA

The ARIMA (AutoRegressive Integrated Moving Average) model is a powerful statistical tool used for time series forecasting. It effectively combines three components: Autoregression (AR), Integration (I), and Moving Average (MA). These components work together to model and predict patterns in time series data.

The Autoregressive (AR) component involves regressing the variable on its own lagged (past) values. An AR(p) model expresses the current value of the series as a linear function of its previous p values:

$$X_t = \alpha + \sum_{i=1}^{p} \phi_i X_{t-i} + \epsilon_t$$

where X_t is the time series at time t, α is a constant, ϕ_i are the autoregressive parameters, and ϵ_t is white noise. The Integration (I) component is used to transform a non-stationary time series into a stationary one by differencing the observations. A series is differenced by subtracting the previous observation from the current observation. If d differences are required to achieve stationarity, the process is repeated d times:

$$Y_t = X_t - X_{t-1}$$

where Y_t is the differenced series. The Moving Average (MA) component models the error term as a linear combination of past error terms. An MA(q) model suggests that the current value of the series is influenced by the errors from the previous q periods:

$$X_t = \mu + \epsilon_t + \sum_{j=1}^{q} \theta_j \epsilon_{t-j}$$

where μ is the mean of the series, θ_j are the moving average parameters, and ϵ_t is white noise.

Combining these components, the ARIMA model is denoted as ARIMA(p, d, q), where p is the number of lag observations (autoregressive terms), d is the number of times the observations are differenced to achieve stationarity and q is the size of the moving average window (moving average terms). The comprehensive ARIMA(p, d, q) model equation is:

$$(1 - \sum_{i=1}^{p} \phi_i L^i)(1 - L)^d X_t = (1 + \sum_{j=1}^{q} \theta_j L^j)\epsilon_t$$

where L is the lag operator.

Applying the ARIMA model to the West Bengal rainfall data involves fitting an appropriate ARIMA(p, d, q) model to historical rainfall records. The "forecast" package in RStusio 4.4.0 provides "auto.arima()" function which fit the ARIMA model to a time series with appropriate value of parameters. The ARIMA model's ability to incorporate both past values and past forecast errors makes it a robust tool for accurate and reliable time series forecasting.

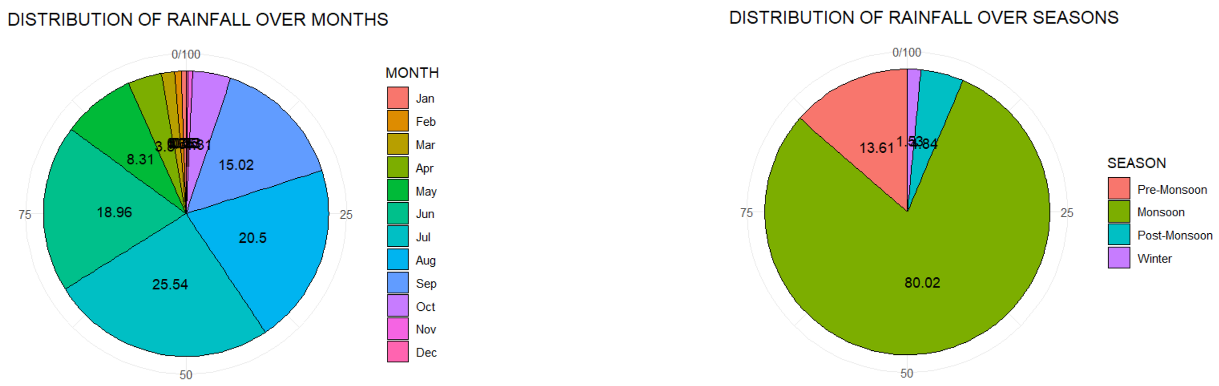
4 Exploratory Data Analysis

Here we analyze various rainfall patterns of six selected districts of West Bengal. One district from each of West Bengal's six agro-climatic zones were selected: Darjeeling (Northern Hill Zone), Coochbehar (Terai-Teesta Alluvial Zone), Maldah (Vindhyan Alluvial Zone), Nadia (Gangetic Alluvial Zone), Purulia (Undulating Red Zone), and South 24 Parganas (Coastal Saline Zone) [3]. Some important plots and tables are included. Rest can be found in the appendix of each subsection.

4.1 EDA for Darjeeling

In Figure 3, the yearly rainfall is plotted for 120 years. The yearly average rainfall in Darjeeling is 3128.725 mm with standard deviation 413.5391 mm. Year with highest (4294.108 mm) and lowest rainfall (2351.912 mm) are 1995 and 1983 respectively. From Figure 3, it can be seen that from seventh decade the rainfall started to decrease and keep decreasing till end of ninth decade of previous century. In the next decade, it deviates a lot and finally shows a regular pattern in current century.

Figure 1 shows the distributions of rainfalls among various months and seasons. July receives maximum percentage (25.54%) of yearly rainfall, followed by August (20.5%). 80.02% of total rainfall occurs in Monsoon. Least percentage (1.53%) of total rainfall occurs in Winter.



(a) Monthwise

(b) Seasonwise

Figure 1: Monthwise and Seasonwise Distribution of Rainfall in Darjeeling

Table 2 shows various descriptive statistics of rainfall in various months in Darjeeling. Table 3 shows similar for various seasons. It is seen that year with highest annual rainfall is year of highest July and Monsoon rainfall, which is 1995 and year with lowest annual rainfall is year of lowest August rainfall, which is 1983.

Figure 4 - 5 show yearly rainfall and it's variation in different months and seasons. It can be seen that greater amount of rainfall and greater variability more or less occur together. The month of January experienced highly irregular rainfall in the middle of previous century and similar for Winter as expected. From Figure 3 and 5, it is seen that yearly and Monsoon rainfall patterns are similar as expected.

Table 1 shows various descriptive statistics of different intensities of yearly rainfall. Most of the days are no rainfall days in Darjeeling and event of heavy rainfall is rare. Maximum number of heavy rainfall has occurred in the year 1995, which is the year of highest rainfall.

Table 1: Statistics of Yearly Rainfall of Different Intensities in Darjeeling

Category	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
No	199.8417	16.2121	236 (1988)	148 (1977)
Light	96.3167	14.2478	139 (1977)	70 (1995)
Moderate	64.3833	10.5231	97 (1971)	44 (1901)
Heavy	4.7083	2.7276	12 (1938, 1995)	0

In Figure 2, the yearly number of various categories of rainfall is plotted. From Figure 2, it can be seen that number of no rainfall days decreased from middle of sixth decade to middle of seventh decade of previous century. Number of light, moderate and heavy rainfall days are more or less constant over years.

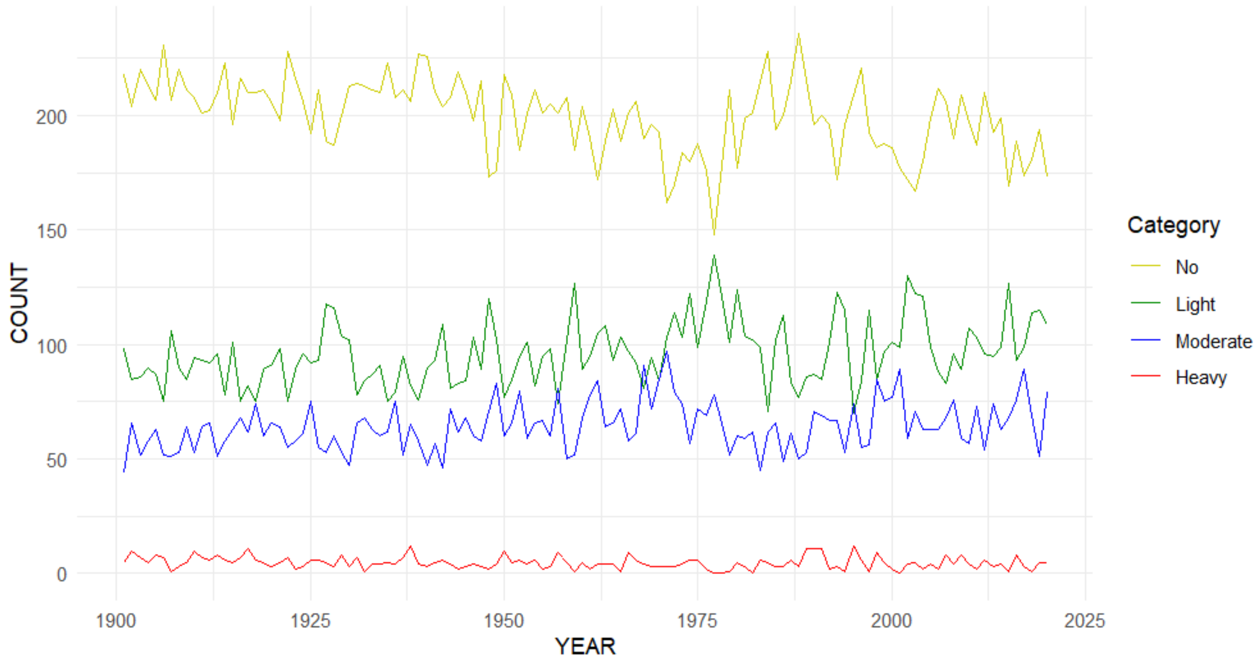


Figure 2: Yearly Plot of Different Intensities of Rainfall in Darjeeling

Figure 6 and 7 show distribution of various intensities of rainfall over different months and seasons respectively. Maximum percentage of no rainfall days occurs in December (15.18%), then January (14.68%). Maximum percentage of no rainfall days (42.66%) occurs in Winter. Maximum percentage of light (52.14%), moderate (85.79%) and heavy (92.92%) rainfall days occurs in Monsoon. Also minimum percentage of light (4.78%), moderate (0.62%) and heavy (0%) rainfall days occurs in Winter. These tell that most and least rainfall occurs in Monsoon and Winter respectively, which is very obvious from Figure 3 and real life observation.

Table 4 shows various descriptive statistics of various intensities of rainfall in various months in Darjeeling. Table 5 shows similar for various seasons. From Table 4 and 5, it is seen that maximum average number of no (30.3417), light (17.375), moderate (17.3417) and heavy (1.775) rainfall days occur in the months of December, May, July and July respectively. Maximum average number of no rainfall occurs in Winter (85.25) and Monsoon experiences maximum average number of light (50.2167), moderate (55.2333) and heavy (4.375) rainfall days. These infer that Monsoon is the most wet and Winter is the driest season.

Figure 8 - 9 show yearly rainfall of different intensities in different months and seasons. Here also it is seen that more rainfall and more variability occur more or less together.

Appendix

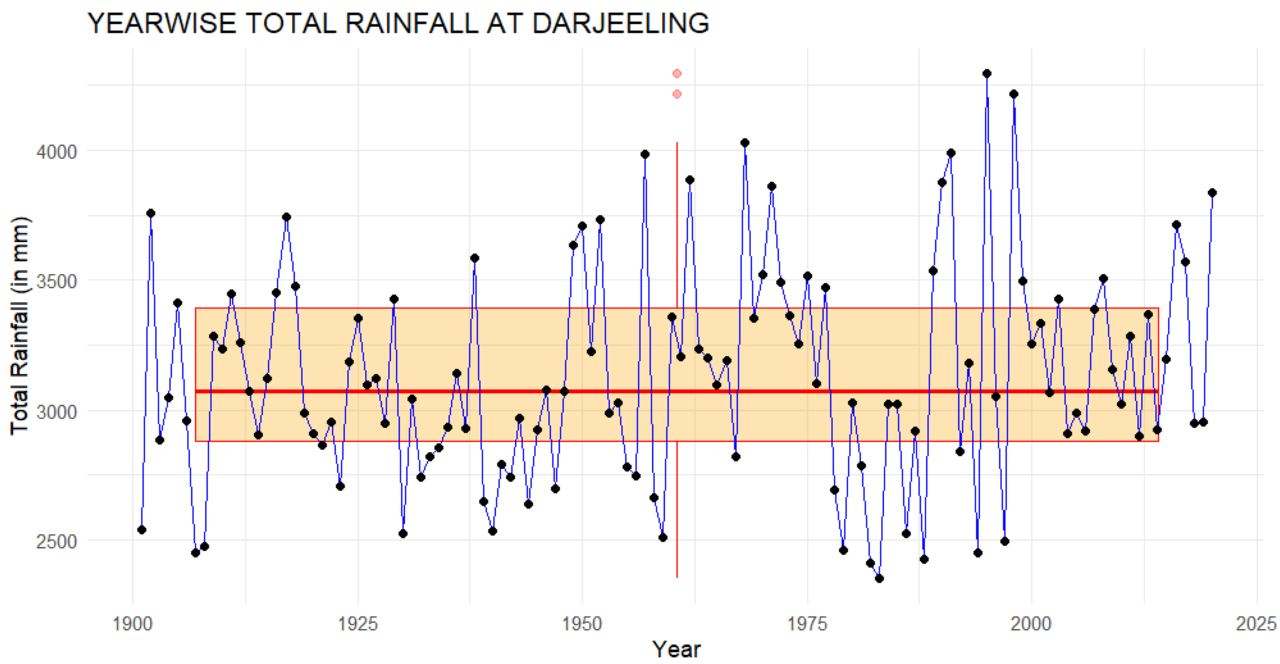


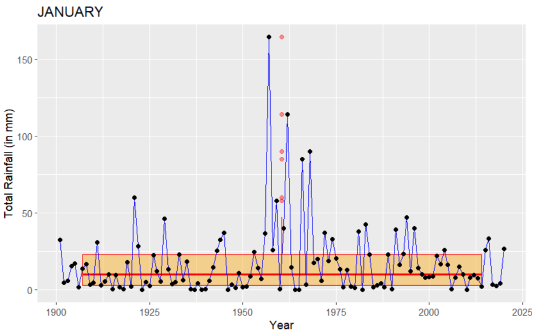
Figure 3: Yearly Rainfall in Darjeeling

Table 2: Monthly Statistics of Rainfall in Darjeeling

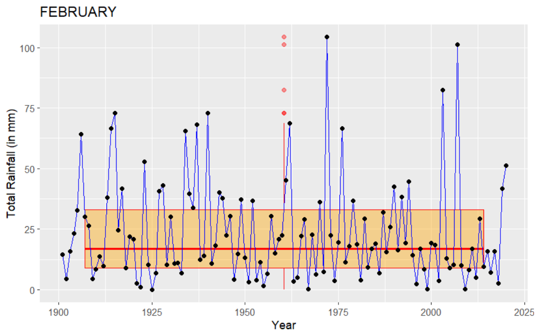
MONTH	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Jan	17.1305	23.1023	164.57 (1957)	0
Feb	23.644	21.2174	104.2526 (1972)	0 (1925)
Mar	46.9025	32.8806	167.3625 (1967)	0 (1909)
Apr	118.8728	59.5439	310.08 (1971)	12.9357 (1939)
May	260.0071	79.7001	512.4667 (1938)	85.42 (1987)
Jun	593.203	171.0503	1206.3375 (1950)	238.2333 (1988)
Jul	799.0451	171.2123	1282.6107 (1995)	436.3357 (1956)
Aug	641.3203	164.4857	1125.7931 (1998)	275.581 (1983)
Sep	470.0396	154.2431	1112.95 (1902)	191.4714 (2005)
Oct	134.9136	105.3129	692.8857 (1929)	10.7667 (1907)
Nov	16.5643	29.2133	222.75 (1912)	0
Dec	7.0818	11.5616	69.25 (1979)	0

Table 3: Seasonal Statistics of Rainfall in Darjeeling

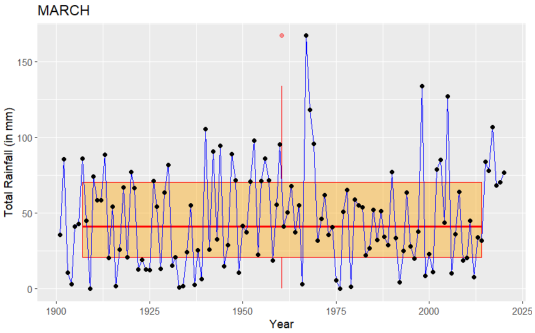
SEASON	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Pre-Monsoon	425.7823	108.306	763.186 (1971)	180.9764 (1979)
Monsoon	2503.6081	360.5978	3636.2048 (1995)	1794.87 (1959)
Post-Monsoon	151.4779	109.0965	700.8429 (1929)	13.4 (1988)
Winter	47.8563	35.1791	209.7933 (1957)	2.3429 (1925)



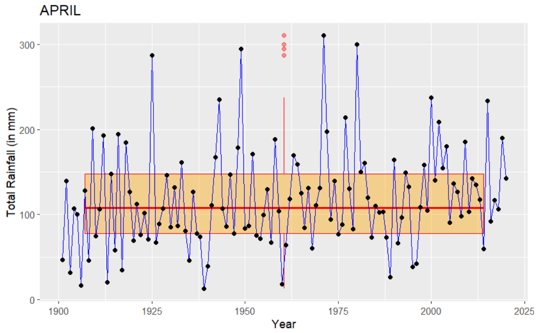
(a) January



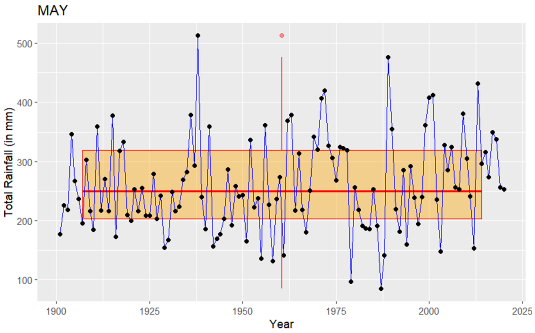
(b) February



(c) March



(d) April



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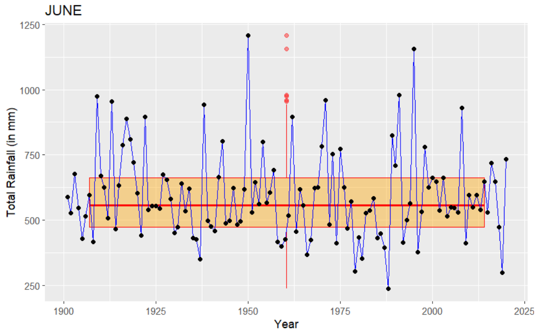

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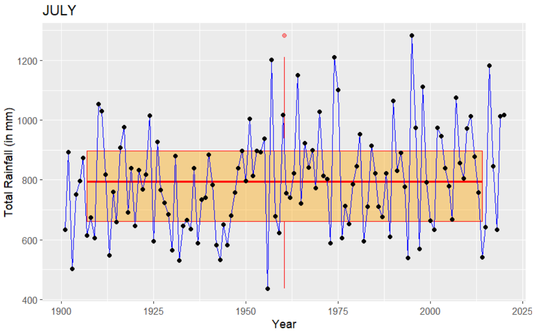
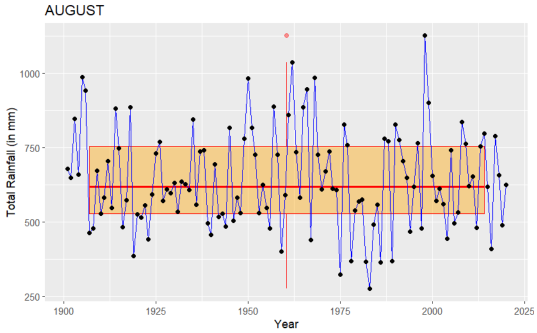


(g) July



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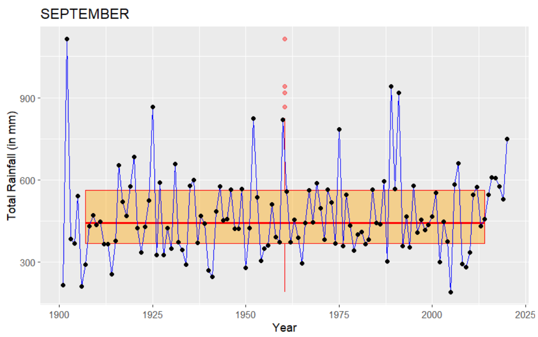
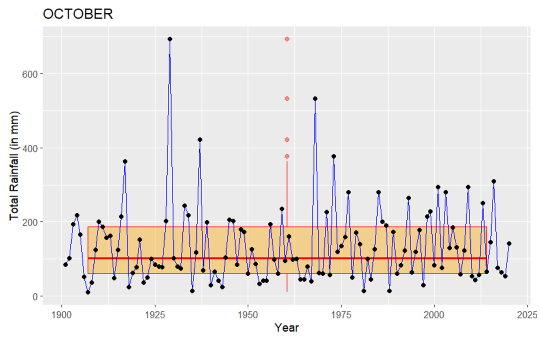
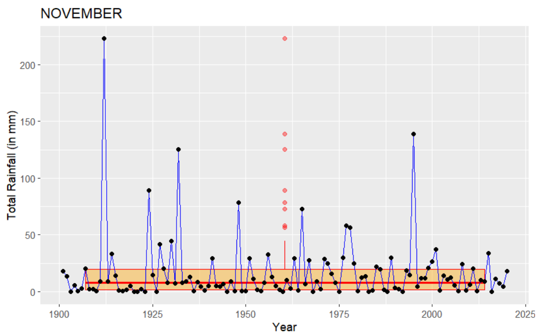


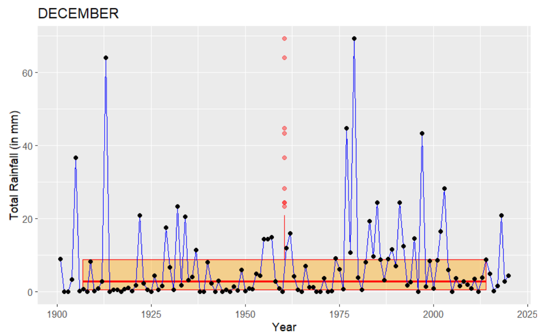
(i) September



(j) October

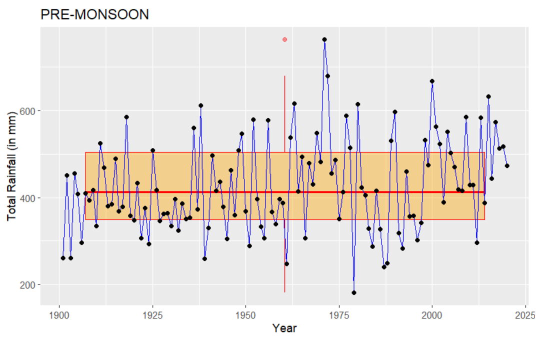


(k) November

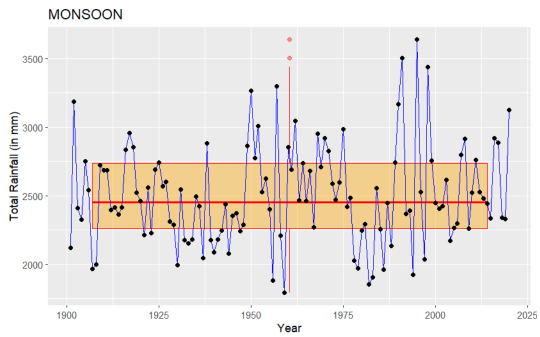


(l) December

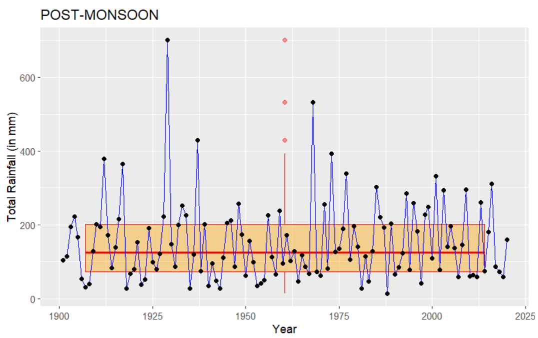
Figure 4: Monthly Rainfall in Darjeeling



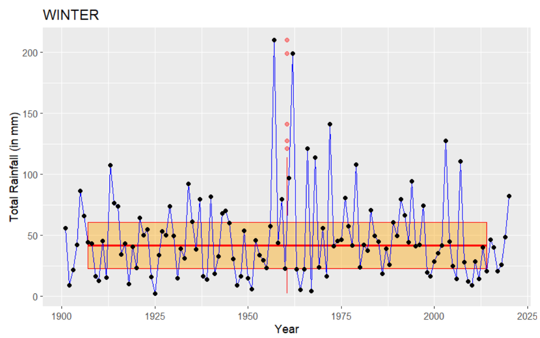
(a) Pre-Monsoon



(b) Monsoon

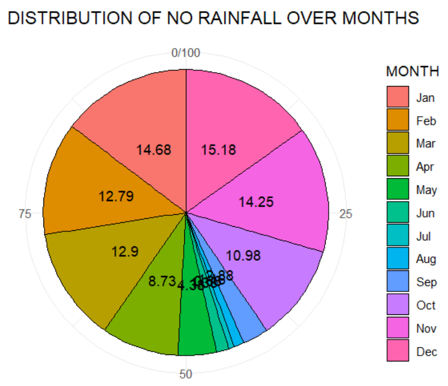


(c) Post-Monsoon

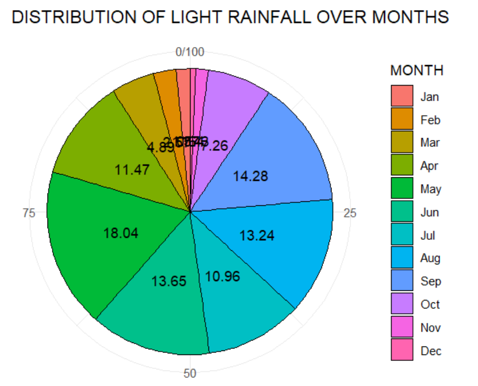


(d) Winter

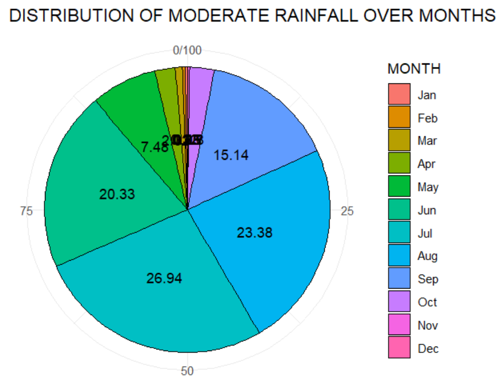
Figure 5: Seasonal Rainfall in Darjeeling



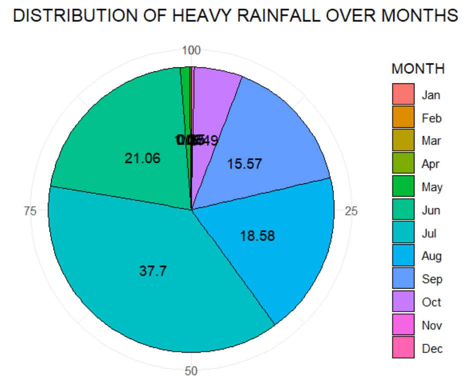
(a) No Rainfall



(b) Light Rainfall

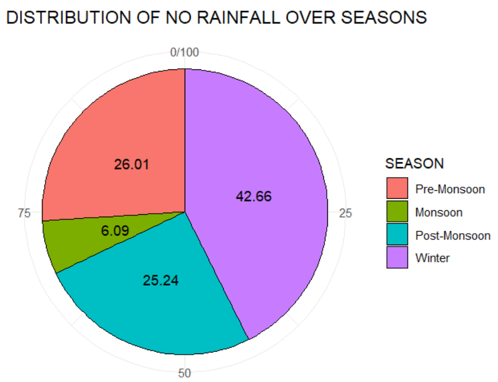


(c) Moderate Rainfall

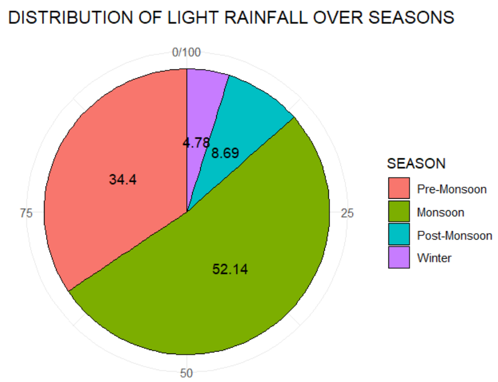


(d) Heavy Rainfall

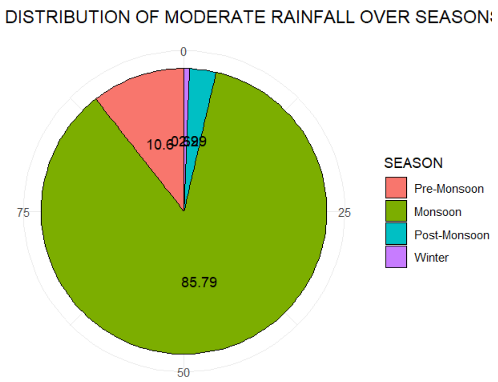
Figure 6: Distribution of Various Intensities of Rainfall over Months in Darjeeling



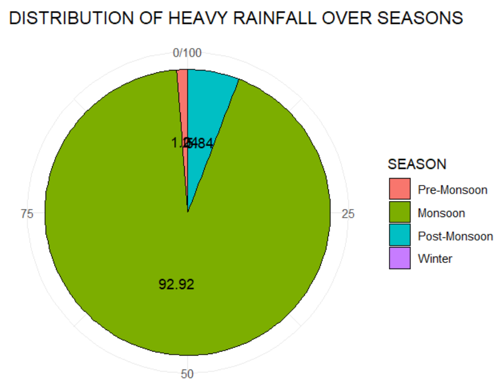
(a) No Rainfall



(b) Light Rainfall



(c) Moderate Rainfall



(d) Heavy Rainfall

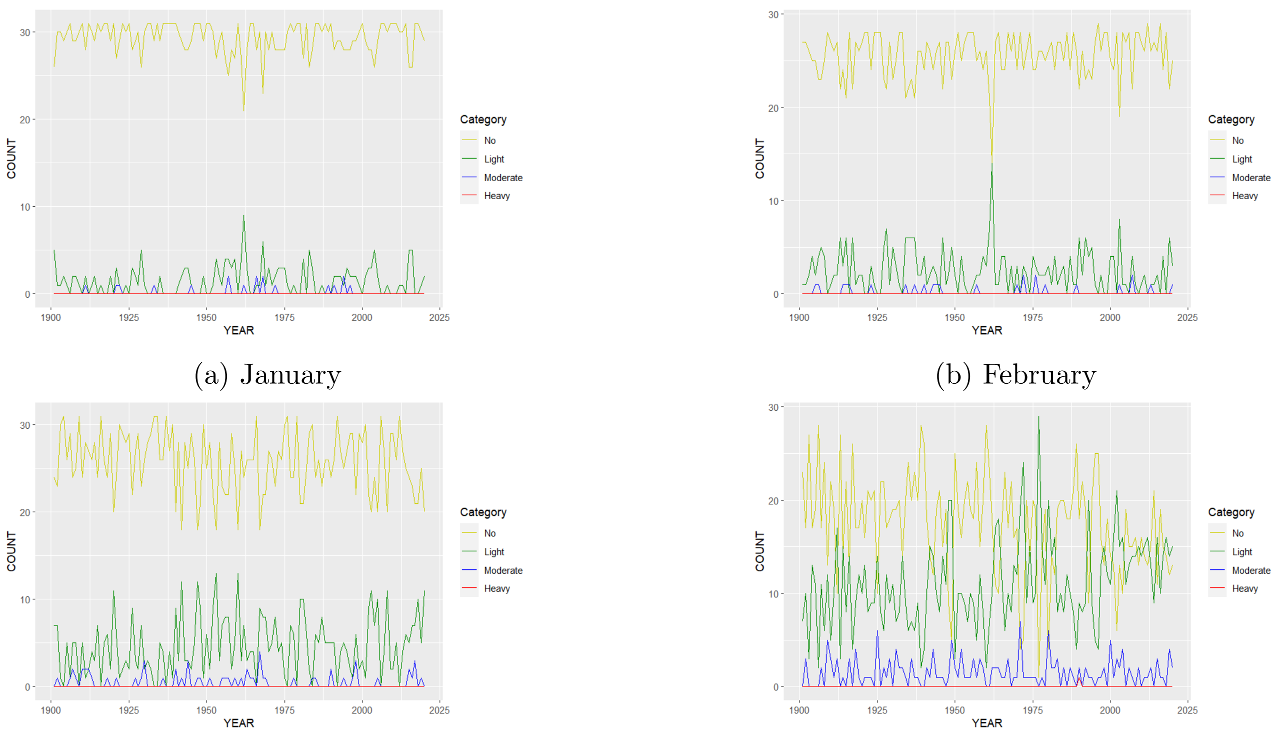
Figure 7: Distribution of Various Intensities of Rainfall over Seasons in Darjeeling

Table 4: Monthly Statistics of Various Intensities Rainfall in Darjeeling

MONTH	STATISTICS	NO	LIGHT	MODERATE	HEAVY
January	Mean	29.3417	1.5083	0.15	0
	SD	1.8051	1.6533	0.4406	0
	Maximum	31	9	2	0
	Minimum	21	0	0	0
February	Mean	25.5667	2.475	0.2083	0
	SD	2.4212	2.2802	0.4636	0
	Maximum	29	14	2	0
	Minimum	14	0	0	0
March	Mean	25.775	4.7083	0.5167	0
	SD	3.513	3.3126	0.8265	0
	Maximum	31	13	4	0
	Minimum	18	0	0	0
April	Mean	17.45	11.05	1.4917	0.0083
	SD	5.3336	4.6901	1.4776	0.0909
	Maximum	28	29	7	1
	Minimum	1	2	0	0
May	Mean	8.7583	17.375	4.8167	0.05
	SD	4.3089	4.2349	2.6739	0.2843
	Maximum	20	26	11	4
	Minimum	0	7	0	0
June	Mean	2.7667	13.15	13.0917	0.9917
	SD	2.4824	3.6047	3.9833	1.2616
	Maximum	12	24	26	6
	Minimum	0	3	5	0
July	Mean	1.325	10.5583	17.3417	1.775
	SD	1.4729	3.4419	3.7025	1.5136
	Maximum	6	19	25	7
	Minimum	0	2	8	0
August	Mean	2.325	12.75	15.05	0.875
	SD	2.1724	4.2529	4.4307	1.1148
	Maximum	8	24	27	5
	Minimum	0	3	5	0
September	Mean	5.7583	13.7583	9.75	0.7333
	SD	3.5754	3.7193	3.2281	1.0934
	Maximum	15	23	21	6
	Minimum	0	7	3	0
October	Mean	21.95	6.9917	1.8	0.2583
	SD	4.3241	3.8133	1.7156	0.7011
	Maximum	31	22	7	4
	Minimum	9	0	0	0
November	Mean	28.4833	1.375	0.125	0.0167
	SD	1.8573	1.6934	0.4754	0.128
	Maximum	30	9	3	1
	Minimum	21	0	0	0
December	Mean	30.3417	0.6167	0.0417	0
	SD	1.0762	1.018	0.1998	0
	Maximum	31	5	1	0
	Minimum	26	0	0	0

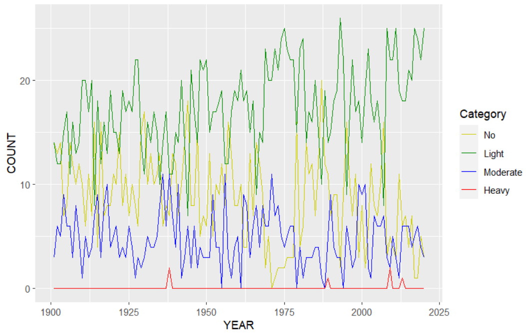
Table 5: Seasonal Statistics of Various Intensities Rainfall in Darjeeling

SEASON	STATISTICS	NO	LIGHT	MODERATE	HEAVY
Pre-Monsoon	Mean	51.9833	33.1333	6.825	0.0583
	SD	9.0829	8.7130	3.2266	0.2971
	Maximum	71	58	18	2
	Minimum	28	14	0	0
Monsoon	Mean	12.1750	50.2167	55.2333	4.375
	SD	6.4209	8.2615	9.4443	2.5757
	Maximum	30	73	80	11
	Minimum	0	28	38	0
Post-Monsoon	Mean	50.4333	8.3667	1.925	0.275
	SD	5.0707	4.5569	1.8581	0.7067
	Maximum	60	26	8	4
	Minimum	35	1	0	0
Winter	Mean	85.25	4.6	0.4	0
	SD	3.4767	3.2542	0.7	0
	Maximum	90	25	3	0
	Minimum	64	0	0	0

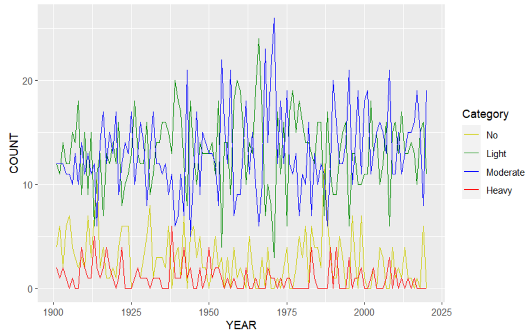


(a) January (b) February

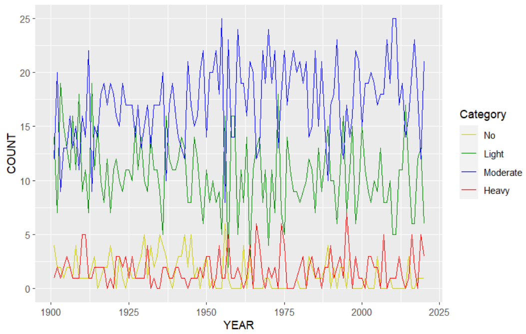
(c) March (d) April



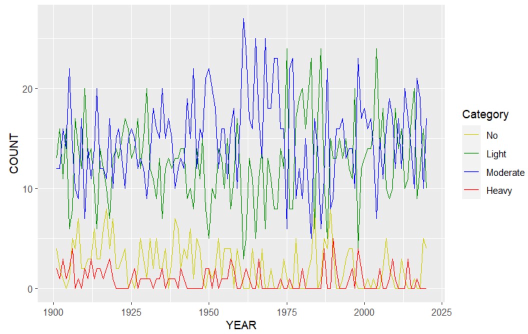
(e) May



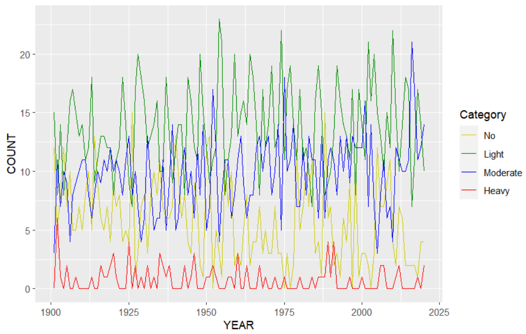
(f) June



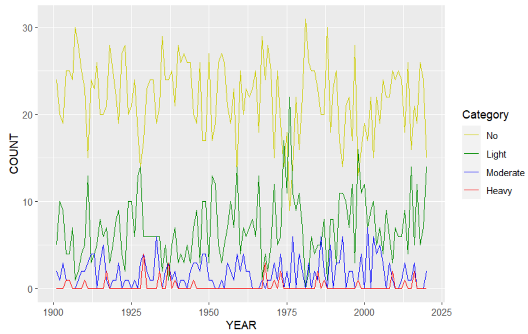
(g) July



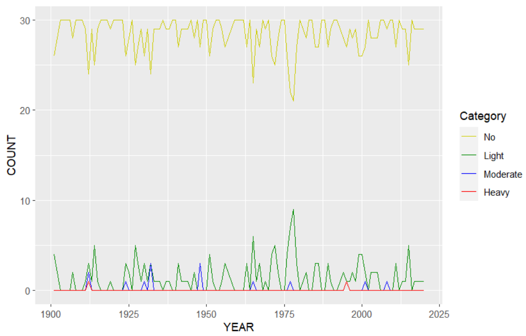
(h) August



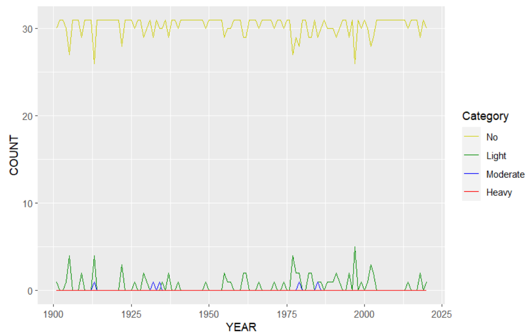
(i) September



(j) October

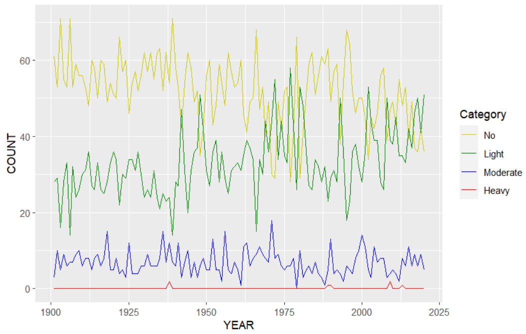


(k) November

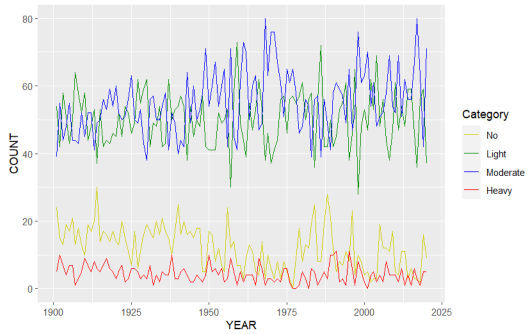


(l) December

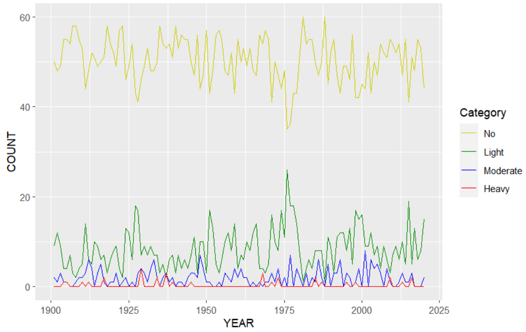
Figure 8: Monthwise Plot of Different Intensities of Rainfall in Darjeeling



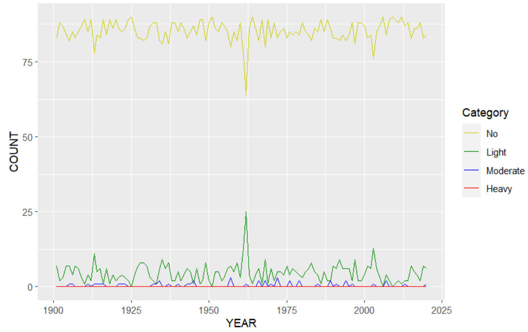
(a) Pre-Monsoon



(b) Monsoon



(c) Post-Monsoon



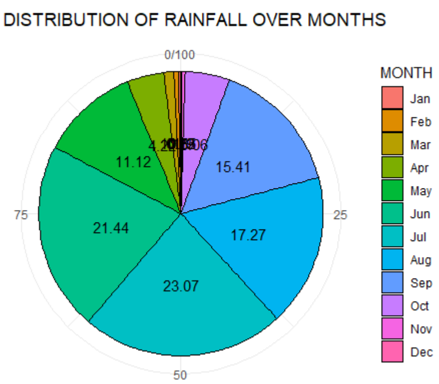
(d) Winter

Figure 9: Seasonwise Plot of Different Intensities of Rainfall in Darjeeling

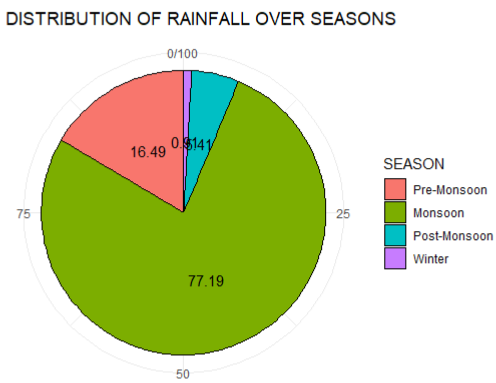
4.2 EDA for Coochbehar

In Figure 12, the yearly rainfall is plotted for 120 years. The yearly average rainfall in Coochbehar is 3243.816 mm with standard deviation 673.3498 mm. Year with highest (5709.813 mm) and lowest rainfall (1761.043 mm) are 1990 and 2018 respectively.From Figure 12, it can be seen that from middle of seventh decade to middle of eight decade more rainfall occurred. Then from middle of ninth decade, it shows a decresing trend till present, except for the year 2020.

Figure 10 shows the distributions of rainfalls among various months and seasons. July receives maximum percentage (23.07%) of yearly rainfall, followed by June (21.44%). 77.19% of total rainfall occurs in Monsoon. Least percentage (0.91%) of total rainfall occurs in Winter.



(a) Monthwise



(b) Seasonwise

Figure 10: Monthwise and Seasonwise Distribution of Rainfall in Coochbehar

Table 7 shows various descriptive statistics of rainfall in various months in Coochbehar. Table 8 shows similar for various seasons. It is seen that year with highest annual rainfall is year of highest

July and Monsoon rainfall, which is 1990.

Figure 13 - 14 show yearly rainfall and it's variation in different months and seasons. In November, variation of rainfall has decreased over years. December experienced a lot more rain in last two decades of previous century, similar for Winter, as expected. From Figure 12 and 14, it is seen that yearly and Monsoon rainfall patterns are similar as expected.

Table 6 shows various descriptive statistics of different intensities of yearly rainfall. Most of the days are no rainfall days in Coochbehar and event of heavy rainfall is rare. Minimum number of heavy rainfall has occurred in the year 2018, which is the year of lowest rainfall.

Table 6: Statistics of Yearly Rainfall of Different Intensities in Coochbehar

Category	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
No	243.15	12.5364	278 (1957)	214 (1921)
Light	60.4917	9.4331	89 (1980)	38 (1960)
Moderate	50.25	7.6018	70 (1931)	32 (2013)
Heavy	11.3583	4.631	26 (1984)	3 (2018)

Figure 11 shows yearly count of various intensities of rainfall. From Figure 11, it can be seen that there is an increasing trend of no rainfall days and decreasing trend of light rainfall days from last quarter of ninth decade of previous century.

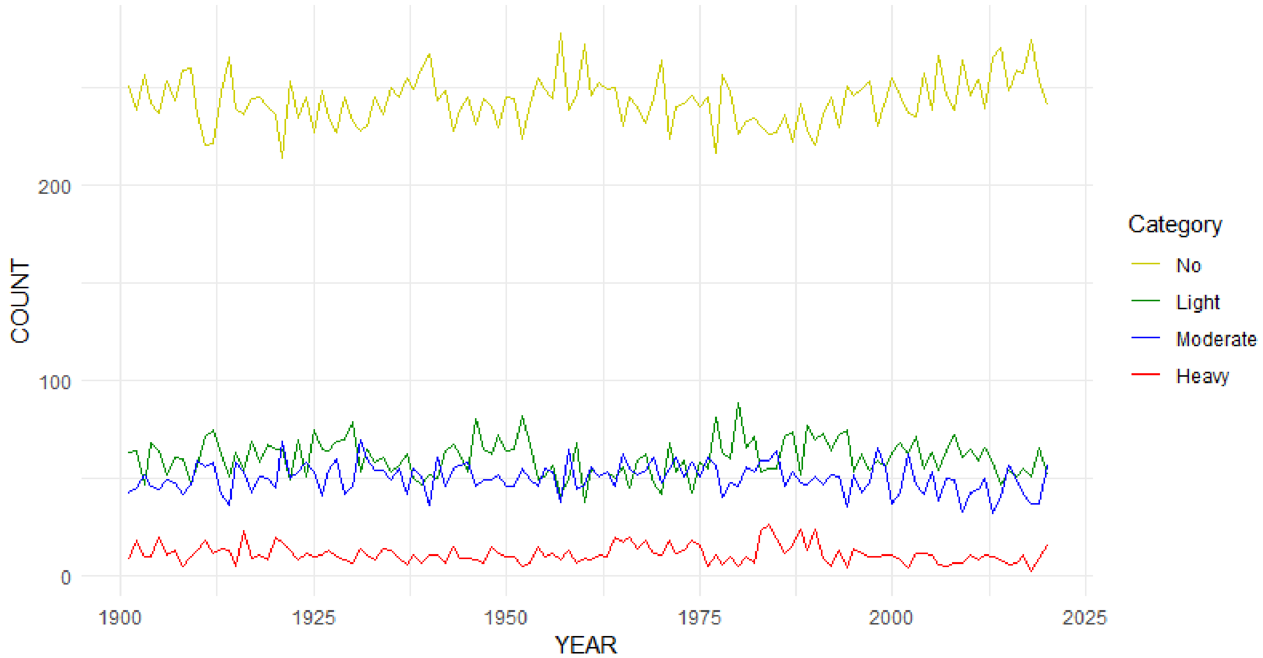


Figure 11: Yearly Plot of Different Intensities of Rainfall in Coochbehar

Figure 15 and 16 show distribution of various intensities of rainfall over different months and seasons respectively. Maximum percentage of no rainfall days occurs in December (12.60%), then January (12.42%). Maximum percentage of no rainfall days (36.01%) occurs in Winter. Maximum percentage of light (61.19%), moderate (70.75%) and heavy (88.92%) rainfall days occurs in Monsoon. Also minimum percentage of light (3.65%), moderate (0.95%) and heavy (0%) rainfall days occurs in Winter. These tell that most and least rainfall occurs in Monsoon and Winter respectively, which is very obvious from Figure 11 and real life observation.

Table 9 shows various descriptive statistics of various intensities of rainfall in various months in Coochbehar. Table 10 shows similar for various seasons. From Table 9 and 10, it is seen that maximum average number of no (30.6333), light (9.9667), moderate (10.4833) and heavy (3.3333) rainfall days occur in the months of December, August, June and July respectively. Maximum average number of no rainfall occurs in Winter (87.5583) and Monsoon experiences maximum average number of light (37.0167), moderate (35.55) and heavy (10.1) rainfall days. These infer that Monsoon is the most wet and Winter is the driest season.

Appendix

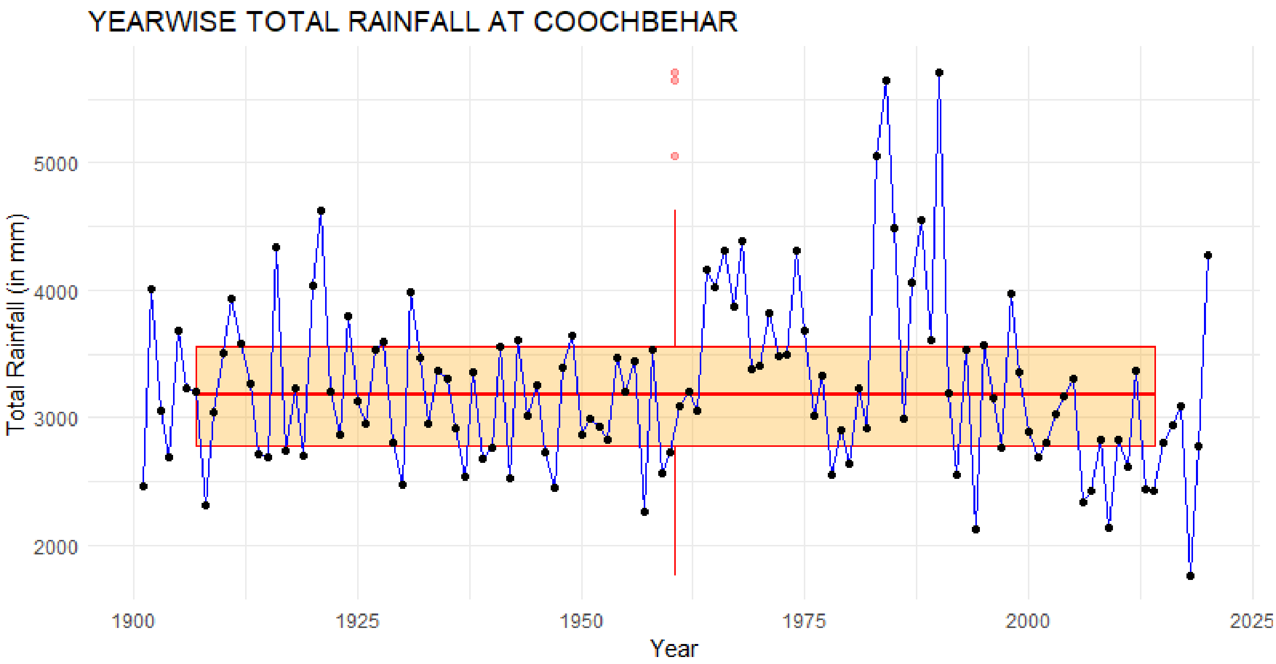


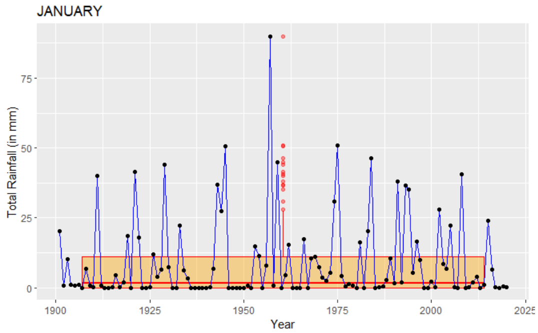
Figure 12: Yearly Rainfall in Coochbehar

Table 7: Monthly Statistics of Rainfall in Coochbehar

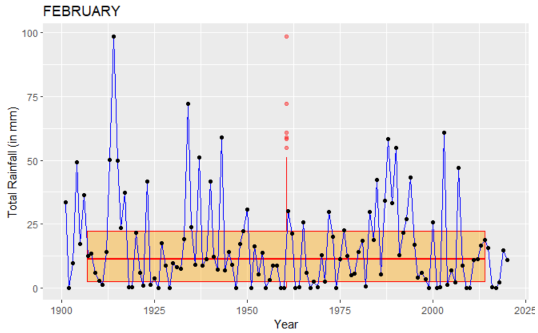
MONTH	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Jan	9.3361	15.1615	89.9 (1957)	0
Feb	16.3139	18.0221	98.575 (1914)	0
Mar	37.204	33.4394	135.52 (1940)	0
Apr	136.9603	79.2877	363.84 (1949)	0.52 (1903)
May	360.6623	136.663	878.46 (1921)	165 (1986)
Jun	695.5026	226.0888	1243.2 (1924)	260.55 (1979)
Jul	748.4798	305.7165	1632.2 (1984)	173.5333 (1914)
Aug	560.0956	315.8513	2493.41 (1990)	138.8233 (2006)
Sep	499.842	242.7414	1352.6333 (2020)	125.6333 (1957)
Oct	164.1158	122.0012	602.36 (1911)	0 (1940)
Nov	11.4762	23.938	153.625 (1932)	0
Dec	3.8274	8.9277	43.2667 (1979)	0

Table 8: Seasonal Statistics of Rainfall in Coochbehar

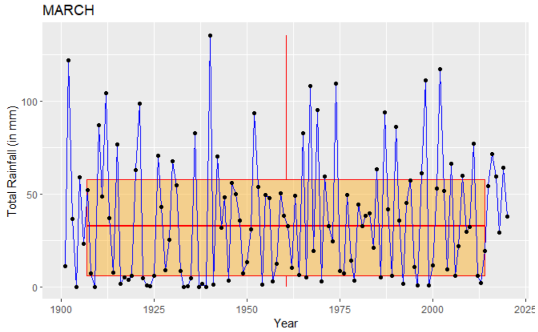
SEASON	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Pre-Monsoon	534.8267	178.6127	1339.08 (1921)	204.925 (1917)
Monsoon	2503.92	594.4453	4826.0567 (1990)	1339.2133 (1994)
Post-Monsoon	175.592	123.3859	605.2 (1911)	6.6 (1940)
Winter	29.4775	24.5997	99.635 (1914)	0



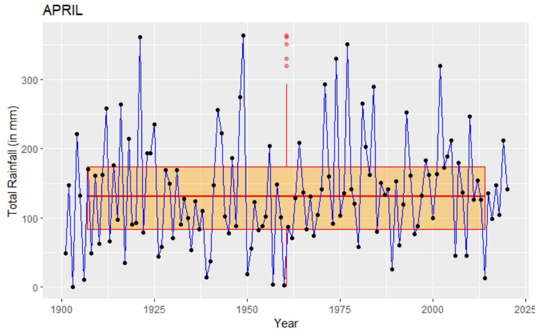
(a) January



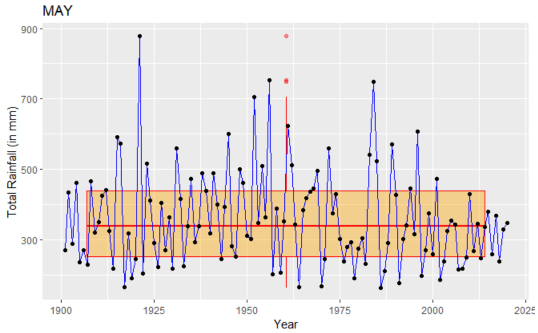
(b) February



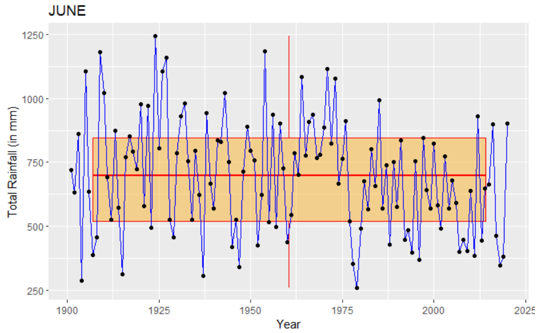
(c) March



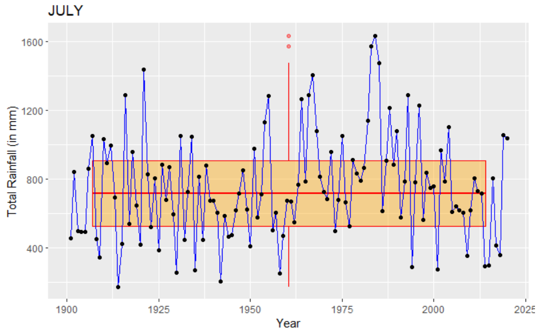
(d) April



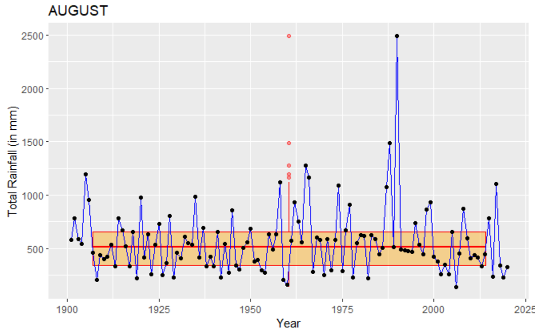
(e) May



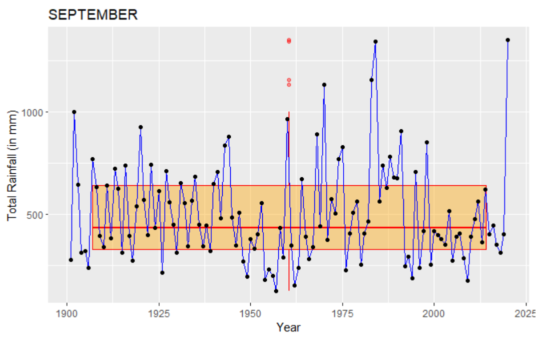
(f) June



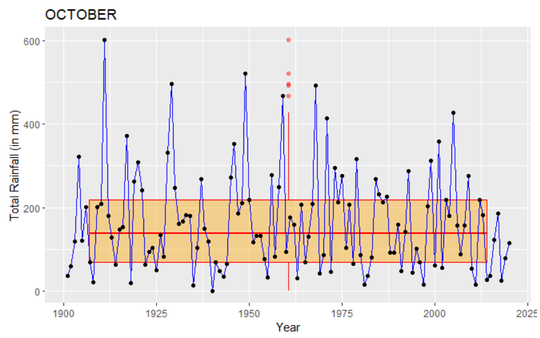
(g) July



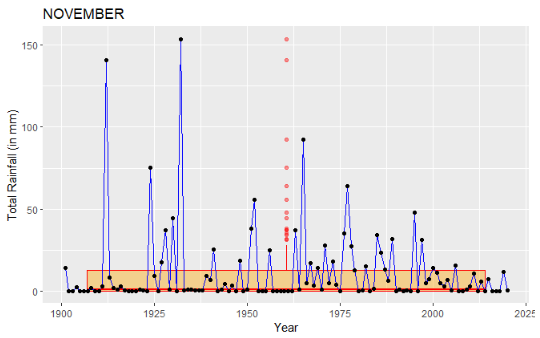
(h) August



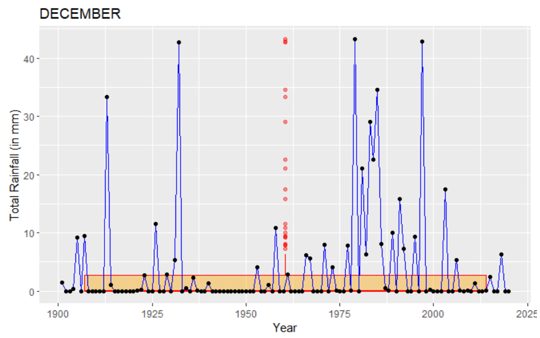
(i) September



(j) October

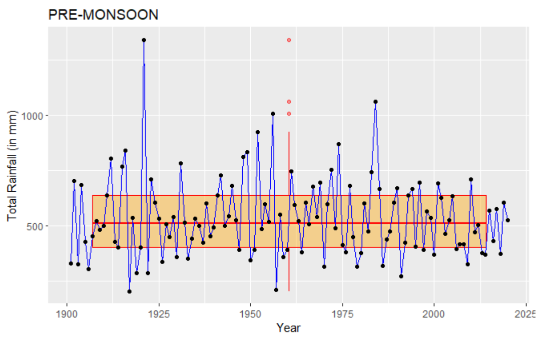


(k) November

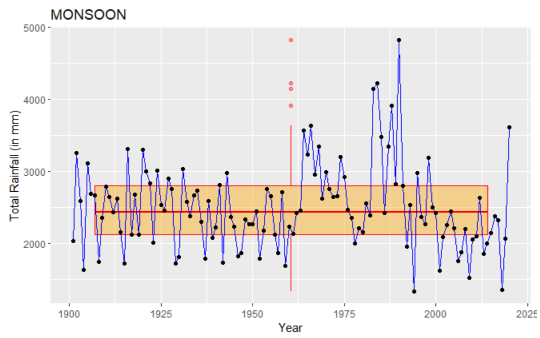


(l) December

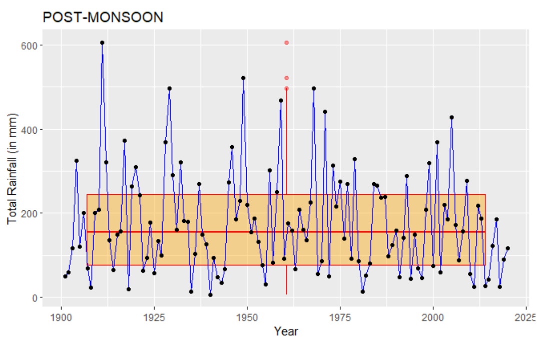
Figure 13: Monthly Rainfall in Coochbehar



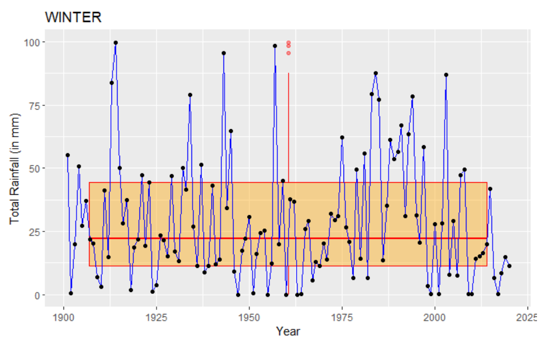
(a) Pre-Monsoon



(b) Monsoon

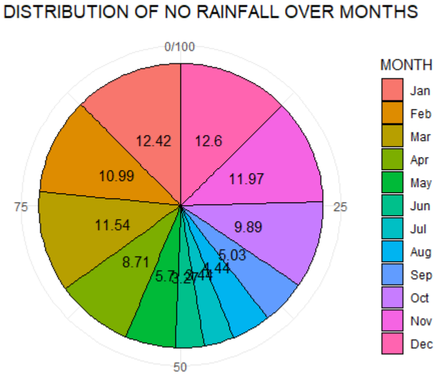


(c) Post-Monsoon

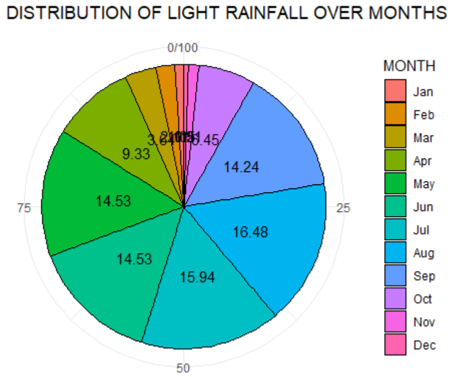


(d) Winter

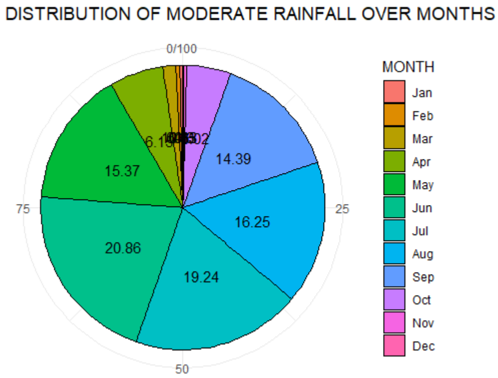
Figure 14: Seasonal Rainfall in Coochbehar



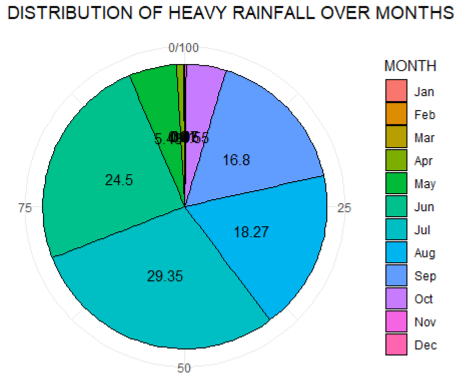
(a) No Rainfall



(b) Light Rainfall

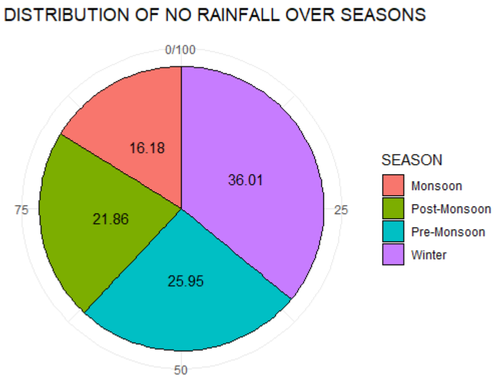


(c) Moderate Rainfall

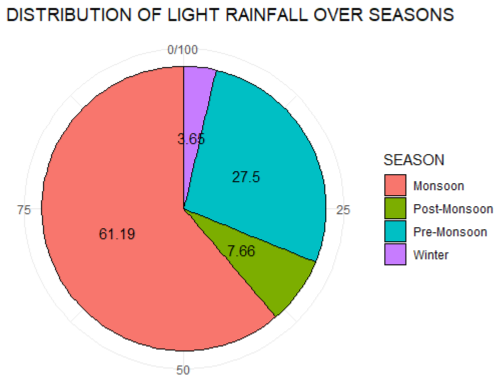


(d) Heavy Rainfall

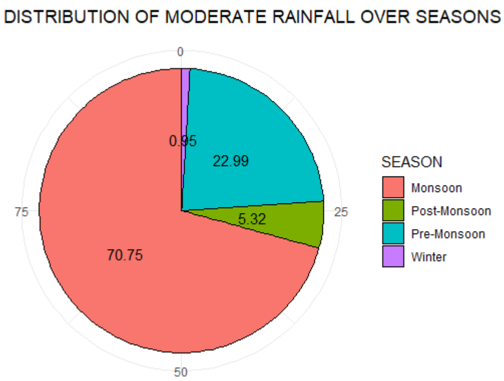
Figure 15: Distribution of Various Intensities of Rainfall over Months in Coochbehar



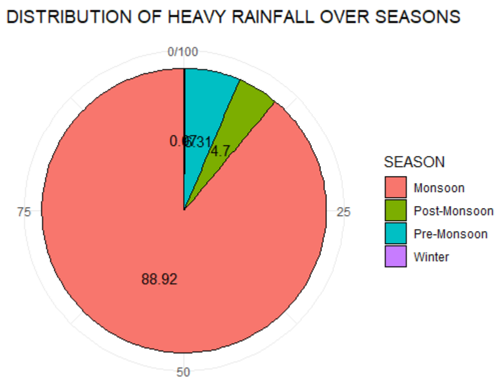
(a) No Rainfall



(b) Light Rainfall



(c) Moderate Rainfall



(d) Heavy Rainfall

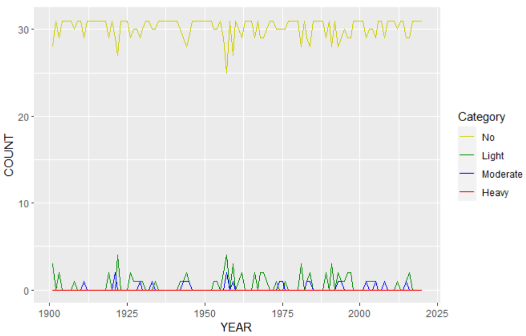
Figure 16: Distribution of Various Intensities of Rainfall over Seasons in Coochbehar

Table 9: Monthly Statistics of Various Intensities Rainfall in Coochbehar

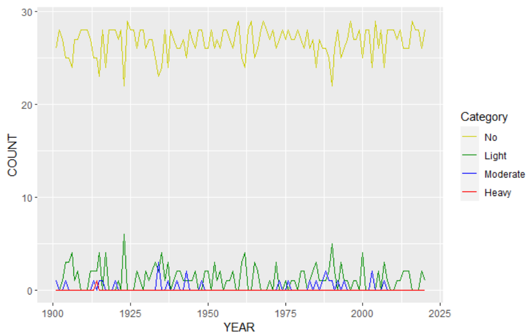
MONTH	STATISTICS	NO	LIGHT	MODERATE	HEAVY
Jan	Mean	30.1917	0.6333	0.1750	0.0000
	SD	1.1350	0.9393	0.4216	0.0000
	Maximum	31	4	2	0
	Minimum	25	0	0	0
Feb	Mean	26.7333	1.2750	0.2333	0.0083
	SD	1.5370	1.2908	0.5281	0.0909
	Maximum	29	6	3	1
	Minimum	22	0	0	0
Mar	Mean	28.0583	2.2000	0.7333	0.0083
	SD	2.3105	1.9348	0.9551	0.0909
	Maximum	31	8	5	1
	Minimum	21	0	0	0
Apr	Mean	21.1750	5.6417	3.0917	0.0917
	SD	4.2420	2.8308	2.0976	0.3415
	Maximum	30	16	9	2
	Minimum	6	0	0	0
May	Mean	13.8667	8.7917	7.7250	0.6167
	SD	3.6718	2.7836	2.9971	0.9590
	Maximum	22	16	16	5
	Minimum	5	3	2	0
Jun	Mean	7.9417	8.7917	10.4833	2.7833
	SD	3.2667	2.8980	2.7202	1.7944
	Maximum	18	16	16	7
	Minimum	0	3	4	0
Jul	Mean	8.3583	9.6417	9.6667	3.3333
	SD	3.6464	2.9034	3.5103	2.3641
	Maximum	19	17	19	11
	Minimum	1	3	1	0
Aug	Mean	10.7917	9.9667	8.1667	2.0750
	SD	3.9852	2.8692	3.2361	2.2441
	Maximum	22	17	15	14
	Minimum	2	2	2	0
Sep	Mean	12.2417	8.6167	7.2333	1.9083
	SD	3.7661	2.7543	2.6196	1.8484
	Maximum	21	17	16	8
	Minimum	2	3	2	0
Oct	Mean	24.0583	3.9000	2.5250	0.5167
	SD	3.4504	2.1618	2.1290	0.8061
	Maximum	31	10	11	4
	Minimum	12	0	0	0
Nov	Mean	29.1000	0.7333	0.1500	0.0167
	SD	1.3565	1.1309	0.4770	0.1280
	Maximum	30	5	3	1
	Minimum	25	0	0	0
Dec	Mean	30.6333	0.3000	0.0667	0.0000
	SD	0.7295	0.6137	0.2494	0.0000
	Maximum	31	3	1	0
	Minimum	28	0	0	0

Table 10: Seasonal Statistics of Various Intensities Rainfall in Coochbehar

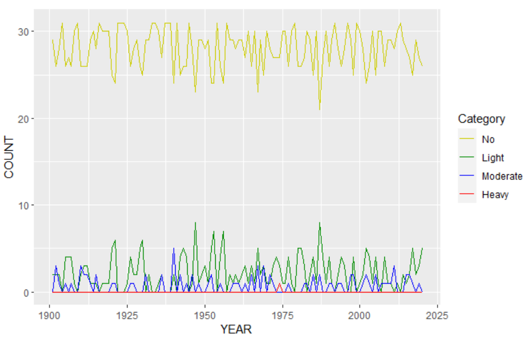
SEASON	STATISTICS	NO	LIGHT	MODERATE	HEAVY
Pre-Monsoon	Mean	63.1000	16.6333	11.5500	0.7167
	SD	6.7890	4.9597	4.1107	1.0423
	Maximum	82	34	25	5
	Minimum	41	5	3	0
Monsoon	Mean	39.3333	37.0167	35.5500	10.1000
	SD	7.6598	6.0635	5.7443	4.3749
	Maximum	59	55	51	24
	Minimum	24	25	22	2
Post-Monsoon	Mean	53.1583	4.6333	2.6750	0.5333
	SD	3.8794	2.6769	2.1531	0.8158
	Maximum	60	14	11	4
	Minimum	38	0	0	0
Winter	Mean	87.5583	2.2083	0.4750	0.0083
	SD	2.0404	1.6528	0.7299	0.0909
	Maximum	91	8	3	1
	Minimum	82	0	0	0



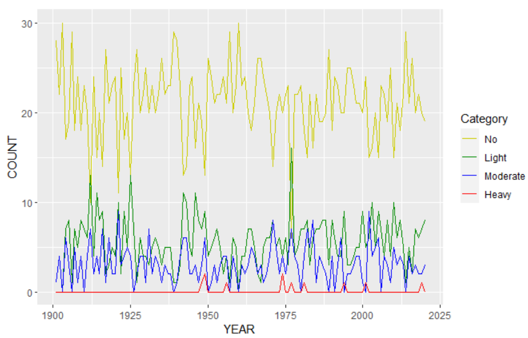
(a) January



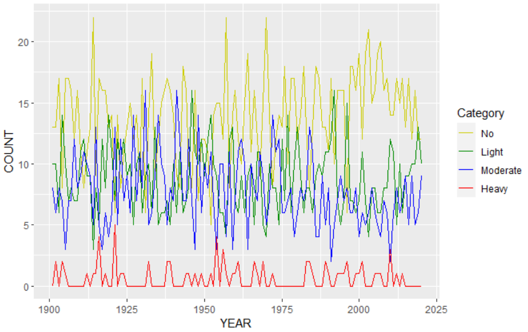
(b) February



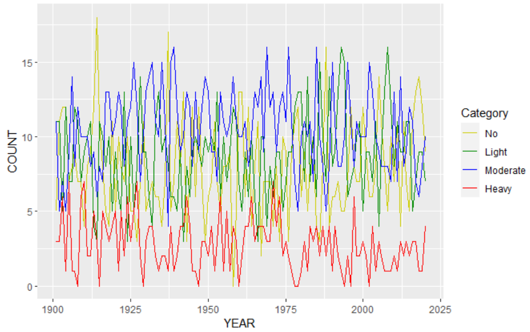
(c) March



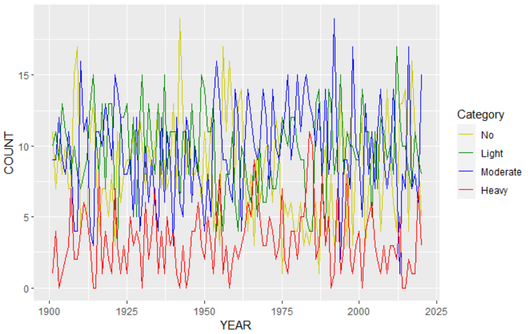
(d) April



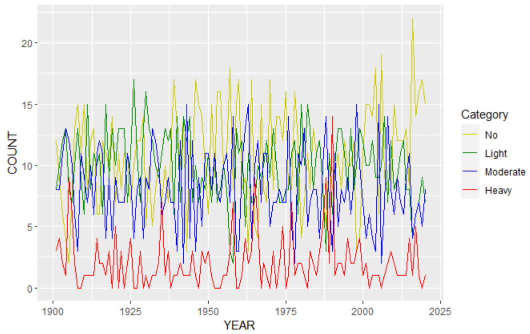
(e) May



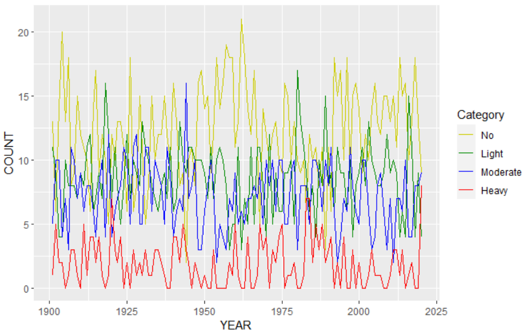
(f) June



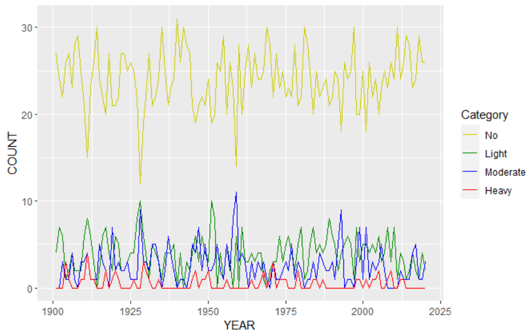
(g) July



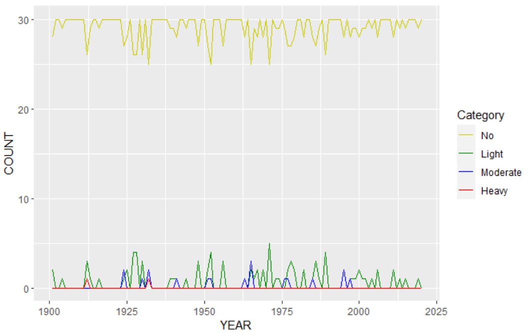
(h) August



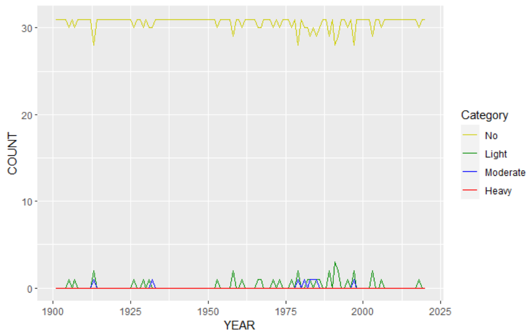
(i) September



(j) October

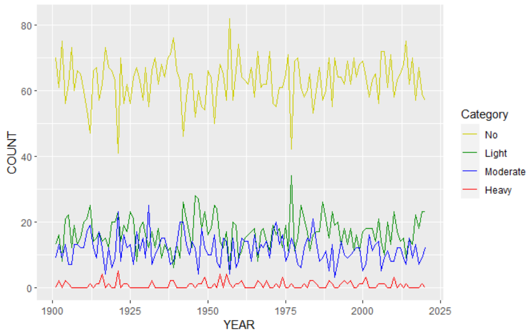


(k) November

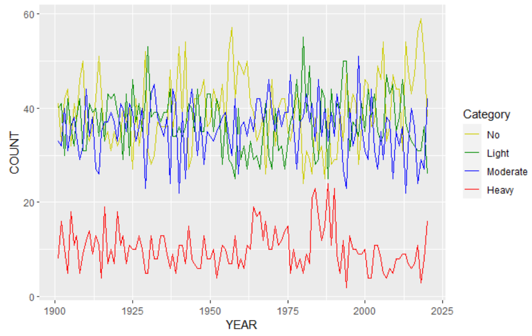


(l) December

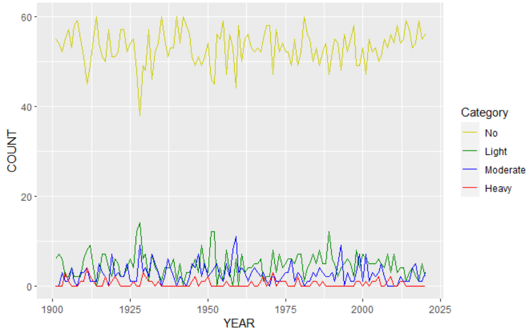
Figure 17: Monthwise Plot of Different Intensities of Rainfall in Coochbehar



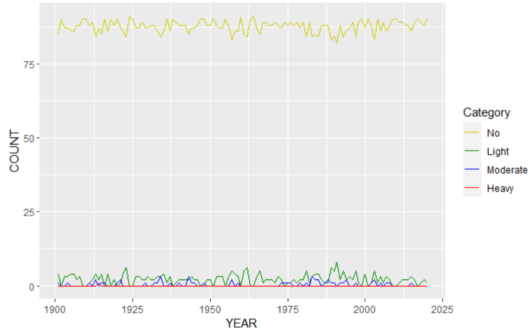
(a) Pre-Monsoon



(b) Monsoon



(c) Post-Monsoon



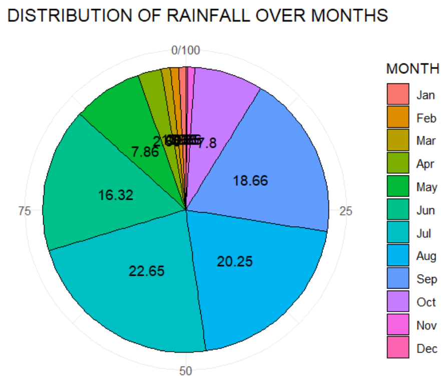
(d) Winter

Figure 18: Seasonwise Plot of Different Intensities of Rainfall in Coochbehar

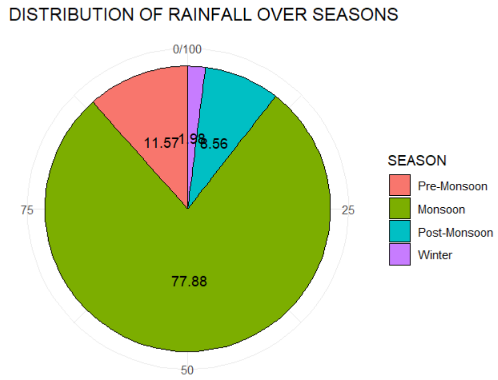
4.3 EDA for Malda

In Figure 21, the yearly rainfall is plotted for 120 years. The yearly average rainfall in Malda is 1475.512 mm with standard deviation 357.8816 mm. Year with highest (2646.826 mm) and lowest rainfall (615.8 mm) are 1980 and 1979 respectively. From Figure 21, it can be seen that in the last two decade of previous century, rainfall there was some inconsistency in rainfall.

Figure 19 shows the distributions of rainfalls among various months and seasons. July receives maximum percentage (22.65%) of yearly rainfall, followed by August (20.25%). 77.88% of total rainfall occurs in Monsoon. Least percentage (1.98%) of total rainfall occurs in Winter.



(a) Monthwise



(b) Seasonwise

Figure 19: Monthwise and Seasonwise Distribution of Rainfall in Malda

Table 12 shows various descriptive statistics of rainfall in various months in Malda. Table 13 shows similar for various seasons. It is seen that year with highest annual rainfall is year of highest July rainfall, which is 1980.

Figure 22 - 23 show yearly rainfall and it's variation in different months and seasons. The month of December experienced highly irregular rainfall in the last quarter of previous century. From Figure 3 and 5, it is seen that yearly and Monsoon rainfall patterns are similar as expected.

Table 11 shows various descriptive statistics of different intensities of yearly rainfall. Most of the days are no rainfall days in Malda and event of heavy rainfall is rare. Maximum number of no rainfall has occured in the year 1979, which is the year of lowest rainfall.

Table 11: Statistics of Yearly Rainfall of Different Intensities in Malda

Category	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
No	285.8417	15.3721	319 (1979)	212 (1976)
Light	49.5667	13.5835	149 (1976)	26 (1989)
Moderate	27.0667	7.5815	45 (1953)	5 (1976)
Heavy	2.775	1.8818	10 (1987)	0

In Figure 20, the yearly number of various categories of rainfall is plotted.

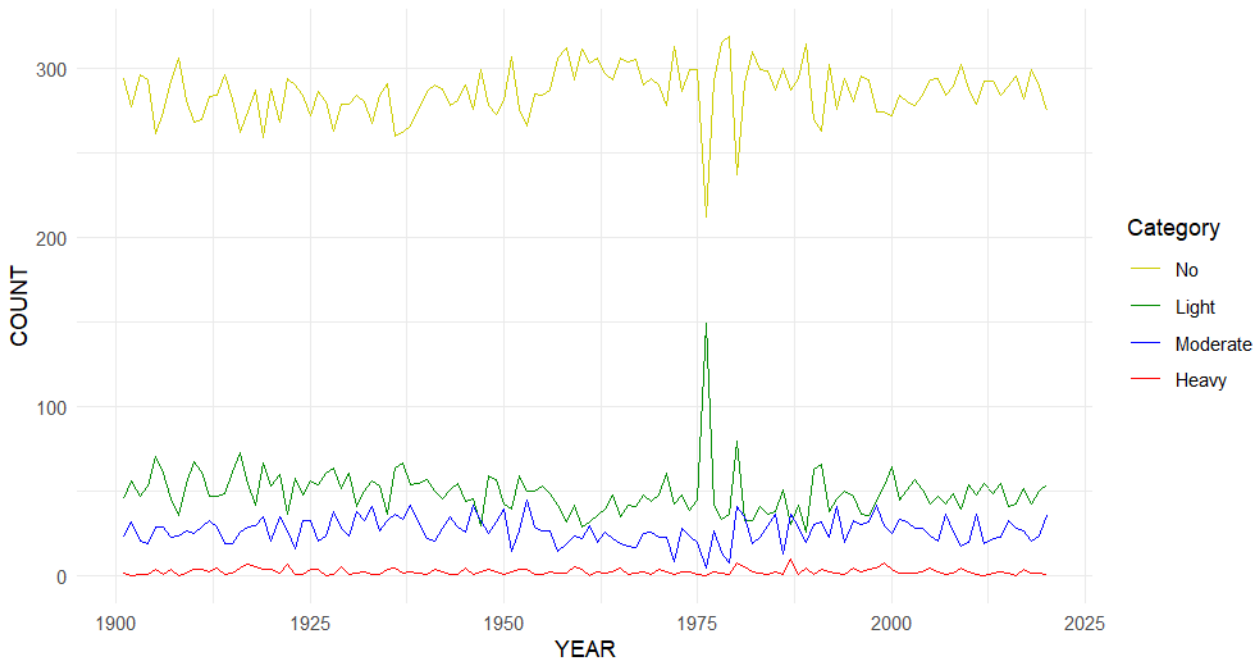


Figure 20: Yearly Plot of Different Intensities of Rainfall in Malda

Figure 24 and 25 show distribution of various intensities of rainfall over different months and seasons respectively. Maximum percentage of no rainfall days occurs in December (10.73%), then January (10.55%). Maximum percentage of no rainfall days (30.71%) occurs in Winter. Maximum percentage of light (73.64%), moderate (78.45%) and heavy (80.78%) rainfall days occurs in Monsoon. Also minimum percentage of light (3.97%), moderate (1.85%) and heavy (0.3%) rainfall days occurs in Winter. These tell that most and least rainfall occurs in Monsoon and Winter respectively, which is very obvious from Figure 21 and real life observation.

Table 14 shows various descriptive statistics of various intensities of rainfall in various months in Malda. Table 15 shows similar for various seasons. From Table 14 and 15, it is seen that maximum average number of no (30.6667), light (10.4833) and moderate (6.4417) rainfall days occur in the months of December, May, July and July respectively. Maximum average number of no rainfall occurs in Winter (87.775) and Monsoon experiences maximum average number of light (36.5), moderate

(21.2333) and heavy (2.2417) rainfall days. These infer that Monsoon is the most wet and Winter is the driest season.

Figure 26 - 27 show yearly rainfall of different intensities in different months and seasons. Here also it is seen that more rainfall and more variability occur more or less together.

Appendix

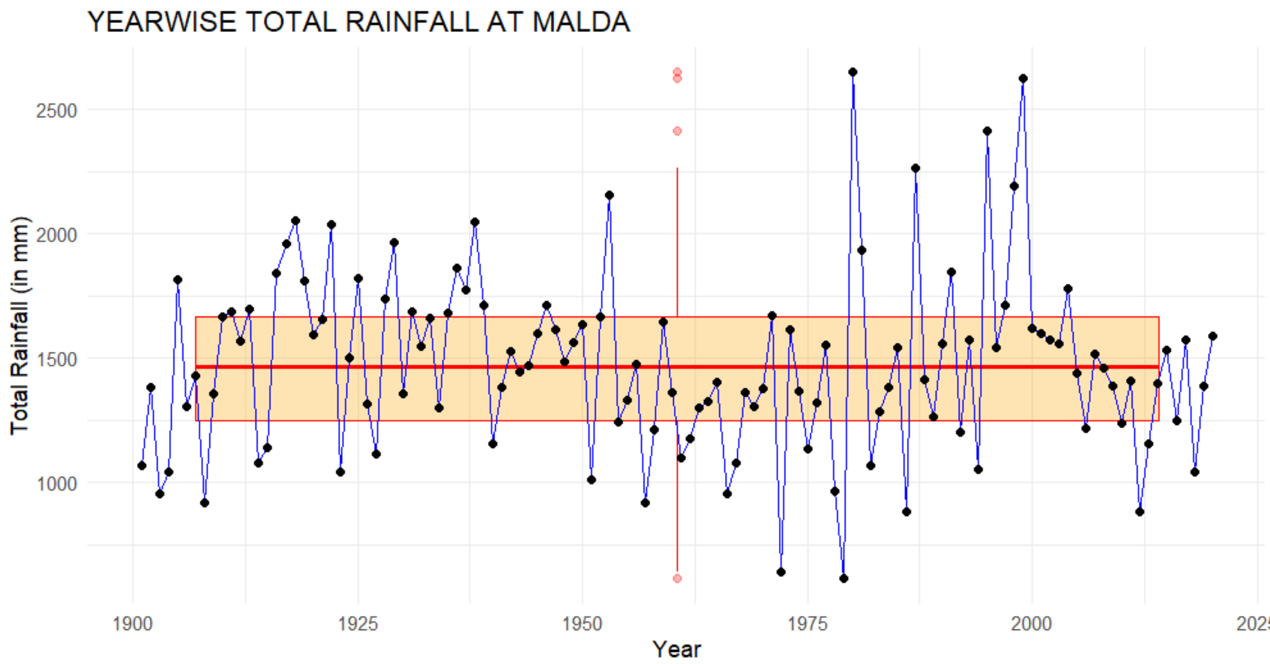


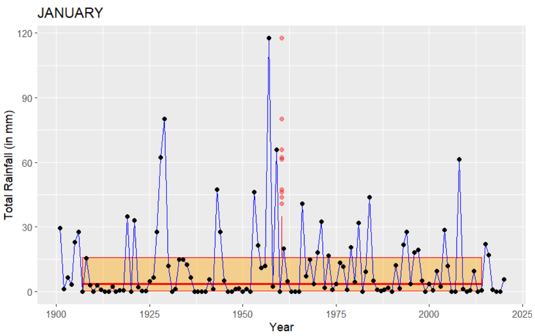
Figure 21: Yearly Rainfall in Malda

Table 12: Monthly Statistics of Rainfall in Malda

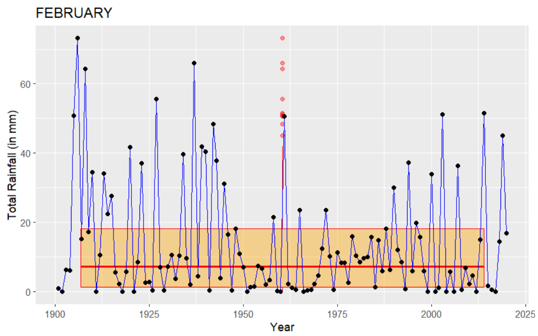
MONTH	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Jan	11.5711	18.3564	117.6 (1957)	0
Feb	14.0828	16.9448	73.1667 (1906)	0
Mar	15.6158	21.1619	113.2333 (1940)	0
Apr	39.1715	45.8498	200.85 (1946)	0
May	115.9908	75.431	537.3667 (1938)	0 (1957)
Jun	240.8649	121.977	580.5 (1950)	25.3 (1958)
Jul	334.1538	128.8219	707.5 (1980)	76.0667 (1903)
Aug	298.8404	147.9528	833.2333 (1918)	51.3 (1986)
Sep	275.2765	161.0741	1068.2833 (1995)	81.9 (1914)
Oct	115.0985	104.1489	531.3667 (1929)	0 (1907, 1981)
Nov	11.2199	23.1814	123.8667 (1932)	0
Dec	3.6261	9.5461	70.1667 (1991)	0

Table 13: Seasonal Statistics of Rainfall in Malda

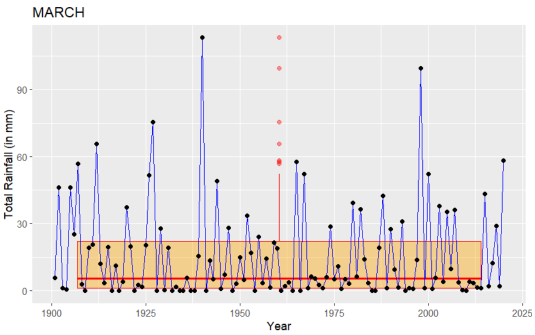
SEASON	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Pre-Monsoon	170.7782	95.1457	539.2333 (1938)	14.45 (1957)
Monsoon	1149.1356	329.0803	2324.65 (1999)	434.7 (1972)
Post-Monsoon	126.3184	105.0928	531.3667 (1929)	0 (1907)
Winter	29.28	25.6735	120.9 (1957)	0



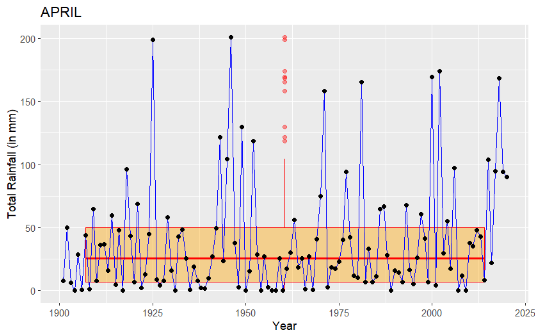
(a) January



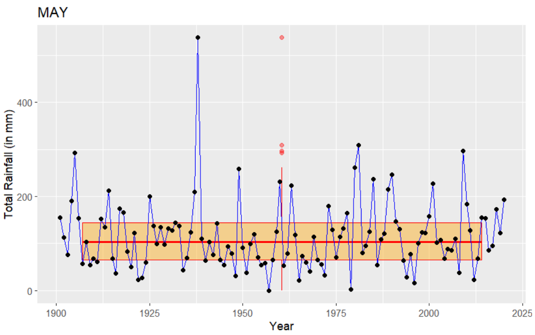
(b) February



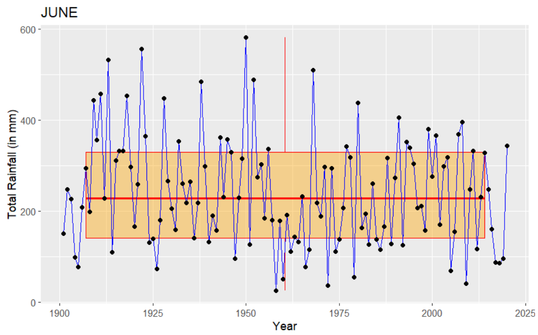
(c) March



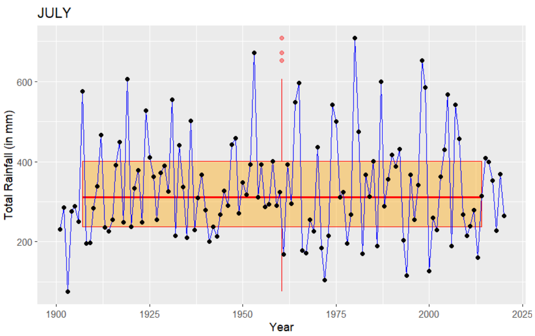
(d) April



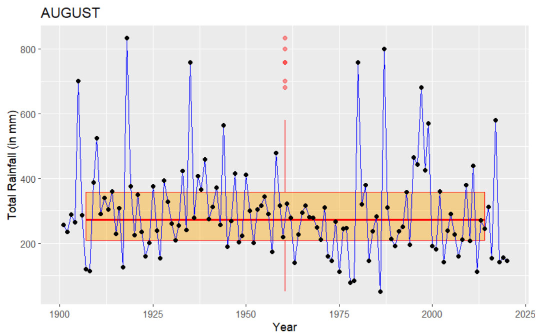
(e) May



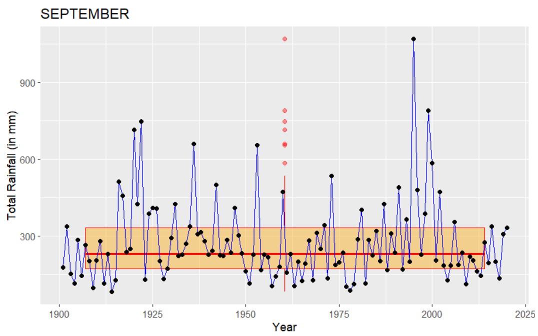
(f) June



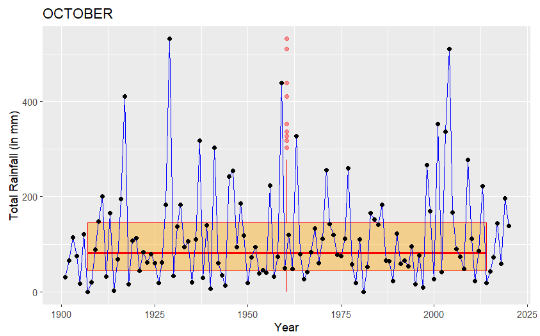
(g) July



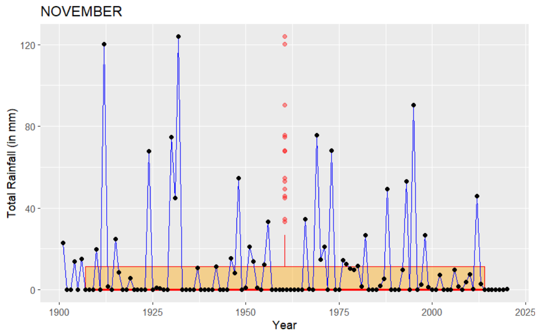
(h) August



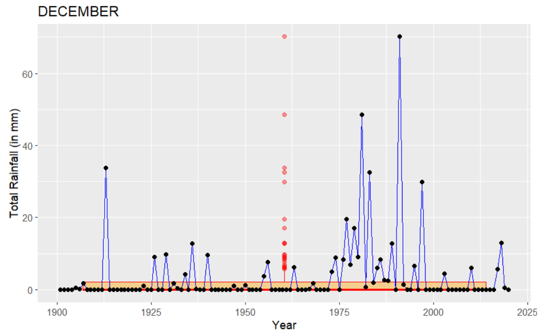
(i) September



(j) October

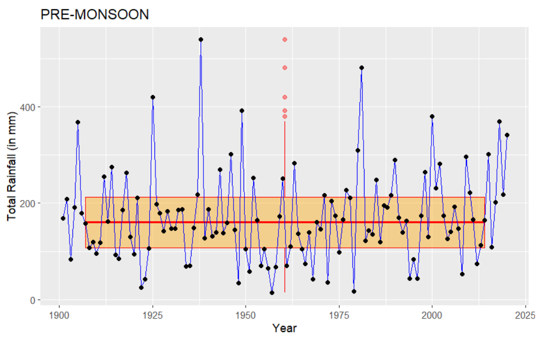


(k) November

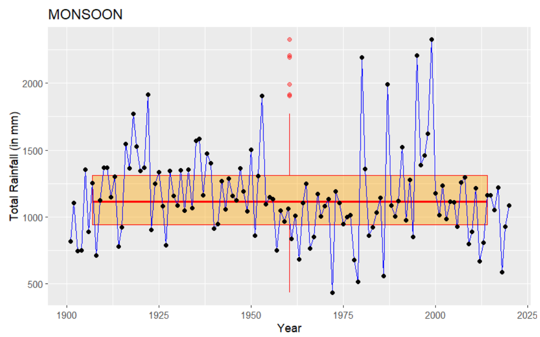


(l) December

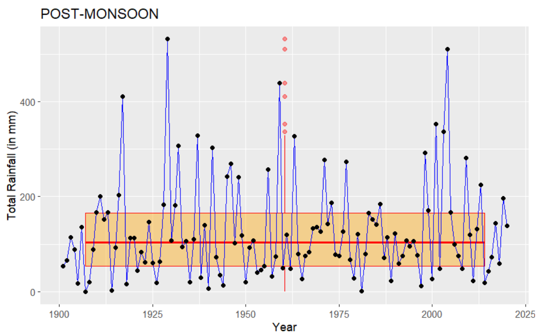
Figure 22: Monthly Rainfall in Malda



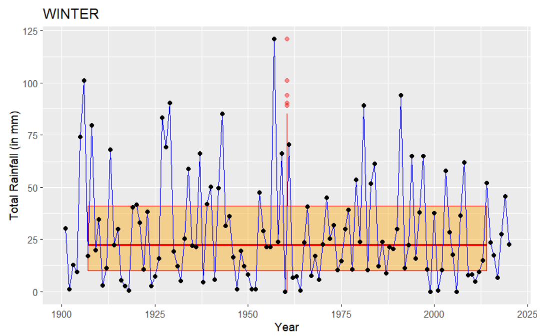
(a) Pre-Monsoon



(b) Monsoon

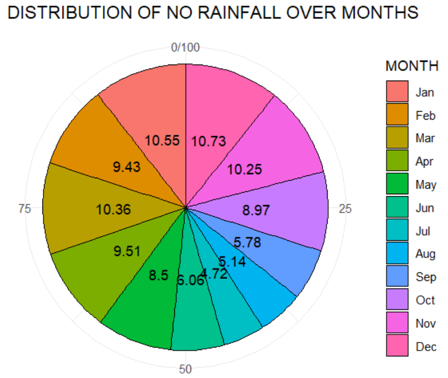


(c) Post-Monsoon

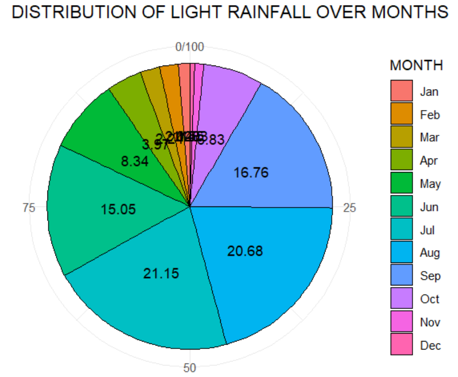


(d) Winter

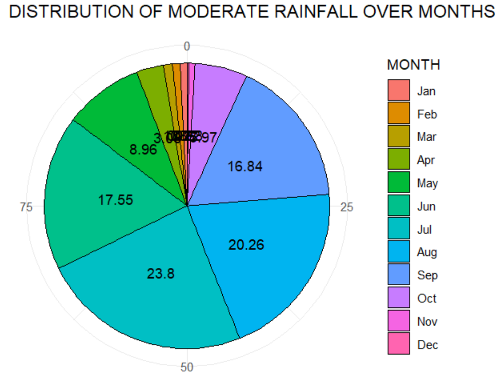
Figure 23: Seasonal Rainfall in Malda



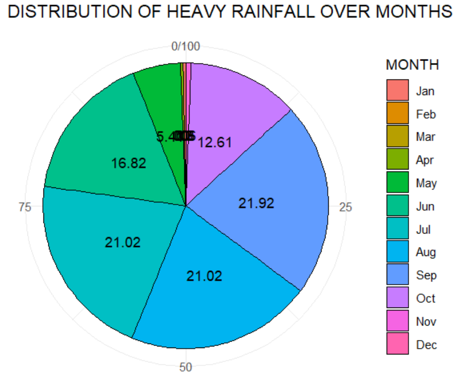
(a) No Rainfall



(b) Light Rainfall

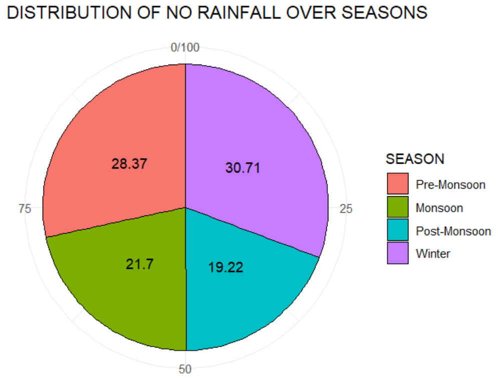


(c) Moderate Rainfall

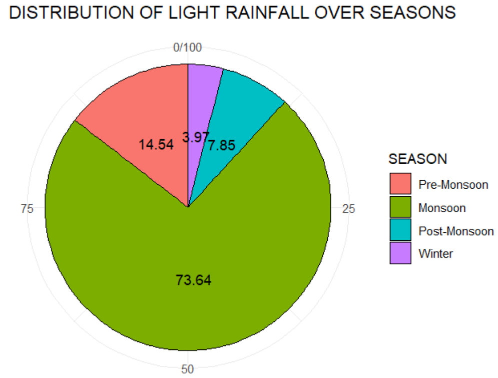


(d) Heavy Rainfall

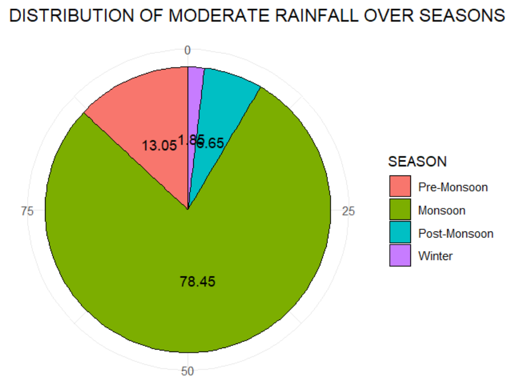
Figure 24: Distribution of Various Intensities of Rainfall over Months in Malda



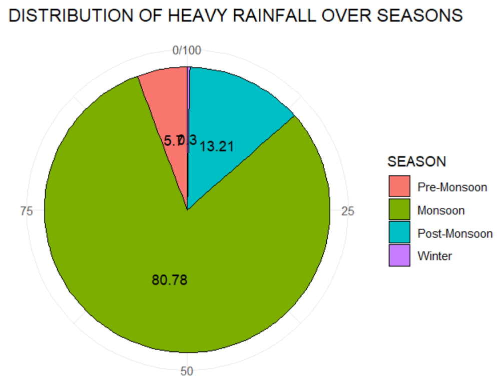
(a) No Rainfall



(b) Light Rainfall



(c) Moderate Rainfall



(d) Heavy Rainfall

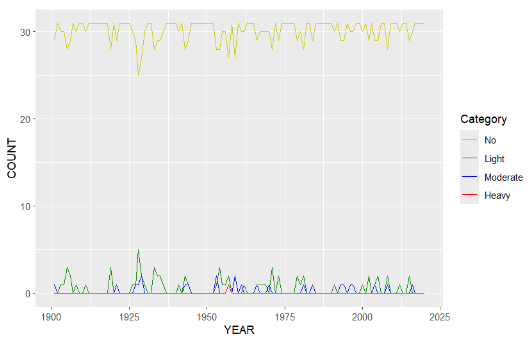
Figure 25: Distribution of Various Intensities of Rainfall over Seasons in Malda

Table 14: Monthly Statistics of Various Intensities Rainfall in Malda

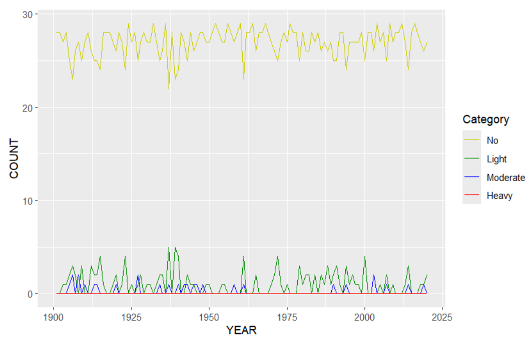
MONTH	STATISTICS	NO	LIGHT	MODERATE	HEAVY
January	Mean	30.15	0.6333	0.2083	0.0083
	SD	1.1878	0.9393	0.4636	0.0909
	Maximum	31	5	2	1
	Minimum	25	0	0	0
February	Mean	26.9583	1.0583	0.2333	0
	SD	1.5133	1.2603	0.4955	0
	Maximum	29	5	2	0
	Minimum	22	0	0	0
March	Mean	29.6267	1.1083	0.275	0
	SD	1.771	1.4877	0.5472	0
	Maximum	31	8	2	0
	Minimum	21	0	0	0
April	Mean	27.1917	1.9667	0.8333	0.0083
	SD	2.501	1.6928	1.2605	0.0909
	Maximum	30	7	5	1
	Minimum	19	0	0	0
May	Mean	24.2917	4.1333	2.425	0.15
	SD	3.2	2.7262	2.6415	0.4406
	Maximum	31	19	7	3
	Minimum	12	0	0	0
June	Mean	17.325	7.4583	4.75	0.4667
	SD	4.7682	3.6604	2.9587	0.67
	Maximum	27	26	16	3
	Minimum	4	1	0	0
July	Mean	13.4917	10.4833	6.4417	0.5833
	SD	4.27	3.6923	3.0078	0.8523
	Maximum	24	31	18	4
	Minimum	0	3	0	0
August	Mean	14.6833	10.25	5.4833	0.5833
	SD	4.1992	3.6429	2.7598	1.0213
	Maximum	25	29	13	6
	Minimum	1	3	0	0
September	Mean	16.525	8.3083	4.5583	0.6083
	SD	3.8535	3.3907	2.2833	0.9064
	Maximum	25	27	12	4
	Minimum	1	2	0	0
October	Mean	25.65	3.3833	1.6167	0.35
	SD	3.7096	3.246	1.4444	0.703
	Maximum	31	31	7	4
	Minimum	0	0	0	0
November	Mean	29.2917	0.5083	0.1833	0.0167
	SD	1.186	0.8944	0.5475	0.128
	Maximum	30	4	4	1
	Minimum	25	0	0	0
December	Mean	30.6667	0.275	0.0583	0
	SD	0.7341	0.605	0.2971	0
	Maximum	31	3	2	0
	Minimum	27	0	0	0

Table 15: Seasonal Statistics of Various Intensities Rainfall in Malda

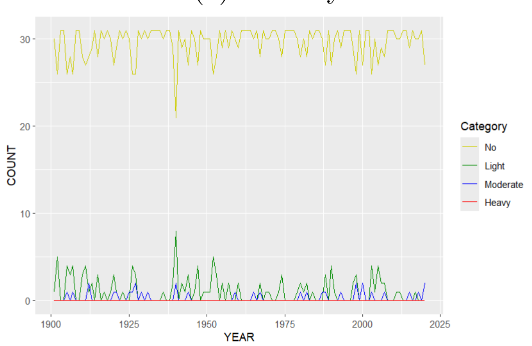
SEASON	STATISTICS	NO	LIGHT	MODERATE	HEAVY
Pre-Monsoon	Mean	81.1	7.2983	3.5333	0.1583
	SD	4.6177	3.7481	2.32	0.4471
	Maximum	90	24	11	3
	Minimum	68	1	0	0
Monsoon	Mean	62.025	36.5	21.2333	2.2417
	SD	11.5546	10.0631	6.4765	1.8028
	Maximum	89	113	38	10
	Minimum	6	19	3	0
Post-Monsoon	Mean	54.9417	3.8917	1.8	0.3667
	SD	3.9397	3.4322	1.5578	0.7063
	Maximum	61	31	7	4
	Minimum	30	0	0	0
Winter	Mean	87.775	1.9667	0.5	0.0083
	SD	1.9934	1.6224	0.7416	0.0909
	Maximum	91	7	3	1
	Minimum	82	0	0	0



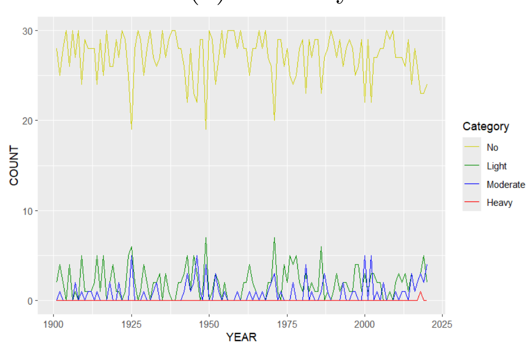
(a) January



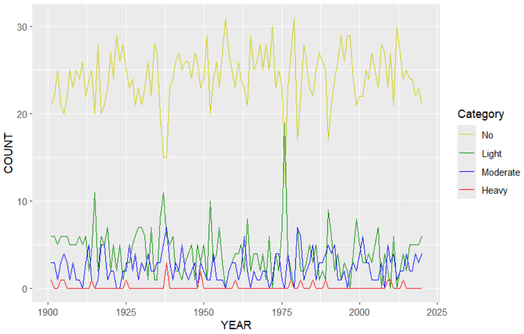
(b) February



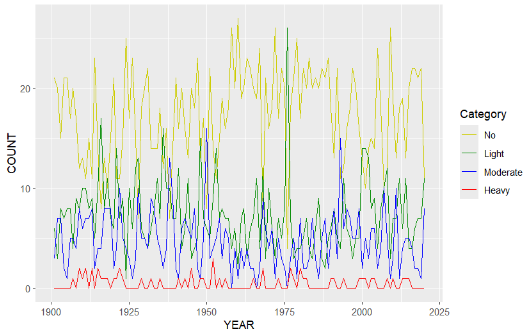
(c) March



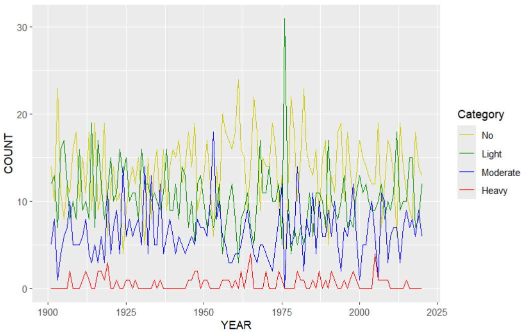
(d) April



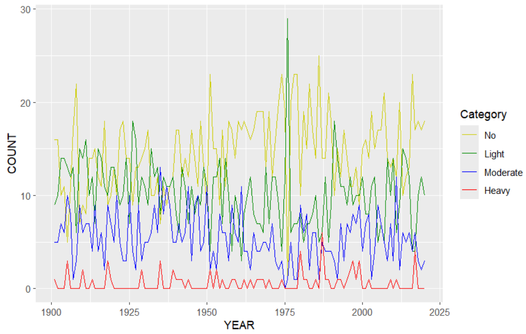
(e) May



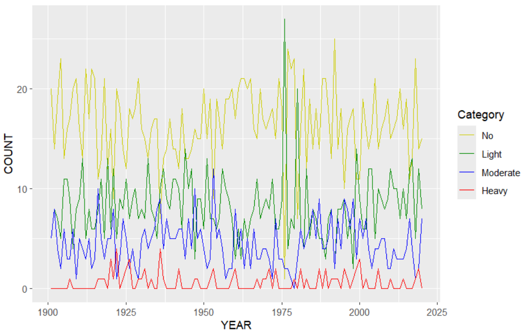
(f) June



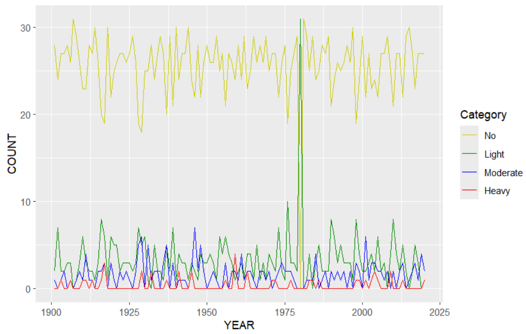
(g) July



(h) August

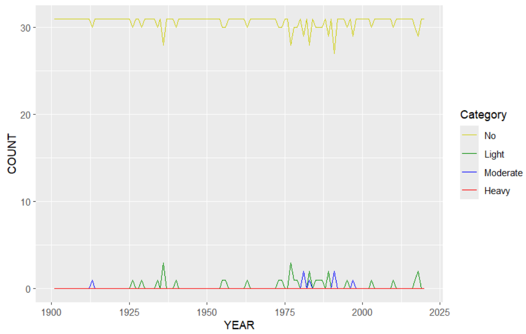


(i) September



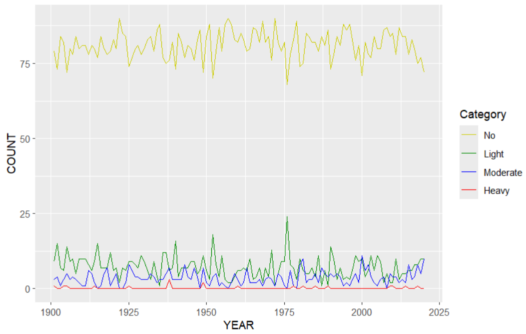
(j) October

(k) November

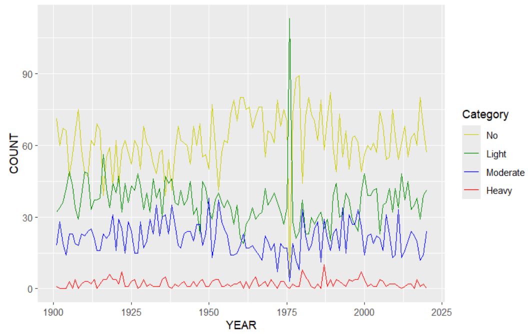


(l) December

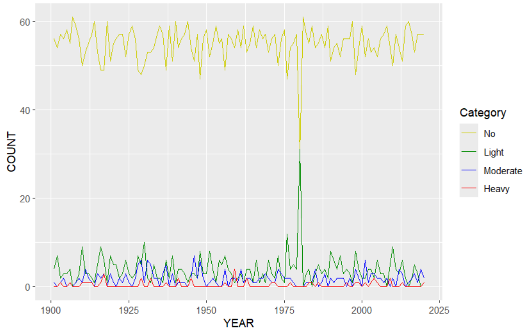
Figure 26: Monthwise Plot of Different Intensities of Rainfall in Malda



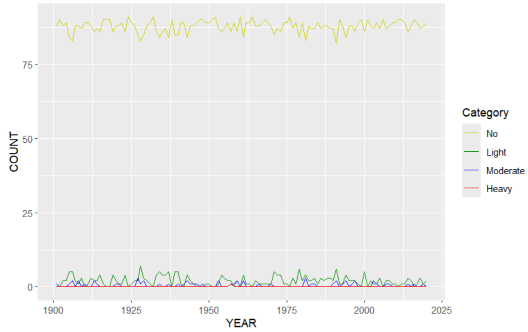
(a) Pre-Monsoon



(b) Monsoon



(c) Post-Monsoon



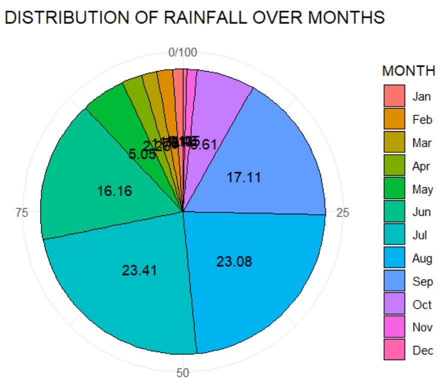
(d) Winter

Figure 27: Seasonwise Plot of Different Intensities of Rainfall in Malda

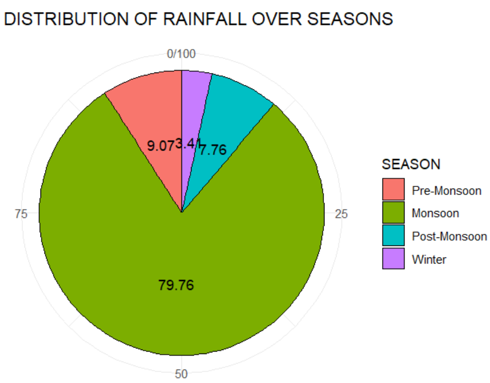
4.4 EDA for Manbhum Purulia

In Figure 30, the yearly rainfall is plotted for 120 years. The yearly average rainfall in Manbhum Purulia is 1350.746 mm with standard deviation 245.49 mm. Year with highest (2081.5 mm) and lowest rainfall (655.17 mm) are 1978 and 1966 respectively. From Figure 30, it can be seen that rainfall started to increase from middle of seventh decade and keep the flow till middle of last decade of previous century. Then it shows a more or less regular pattern in the current century.

Figure 28 shows the distributions of rainfalls among various months and seasons. July receives maximum percentage (23.41%) of yearly rainfall, followed by August (23.08%). 79.76% of total rainfall occurs in Monsoon. Least percentage (3.41%) of total rainfall occurs in Winter.



(a) Monthwise



(b) Seasonwise

Figure 28: Monthwise and Seasonwise Distribution of Rainfall in Manbhum Purulia

Table 17 shows various descriptive statistics of rainfall in various months in Manbhum Purulia. Table 18 shows similar for various seasons. It is seen that year with highest annual rainfall is year of highest September and Monsoon rainfall, which is 1978. Also year with lowest annual rainfall is year of lowest July and Monsoon rainfall, which is 1966.

Figure 31 - 32 show yearly rainfall and it's variation in different months and seasons. It can be seen that greater amount of rainfall and greater variability more or less occur together. December shows very much uncertainty in monthly rainfall in last four decades. From Figure 30 and 32, it is seen that yearly and Monsoon rainfall patterns are similar as expected.

Table 16 shows various descriptive statistics of different intensities of yearly rainfall. Most of the days are no rainfall days in Manbhum Purulia and event of heavy rainfall is rare. Maximum number of heavy rainfall has occurred in the year 1978, which is the year of highest rainfall.

Table 16: Statistics of Yearly Rainfall of Different Intensities in Manbhum Purulia

Category	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
No	270.5333	16.158	311 (1979)	228 (1946)
Light	68.6333	14.8615	102 (1946, 1949)	33 (1984)
Moderate	24.6333	5.7358	37 (1942, 1961)	9 (1966)
Heavy	1.45	1.4251	7 (1978)	0

In Figure 29, the yearly number of various categories of rainfall is plotted. From Figure 29, it can be seen that number of light rainfall days decreased in sixth to eighth decade and then increased. Also number of no rainfall days started to increase seventh decade and keep decreasing till middle of ninth decade of previous century. These give an idea similar as obtained from Figure 30.

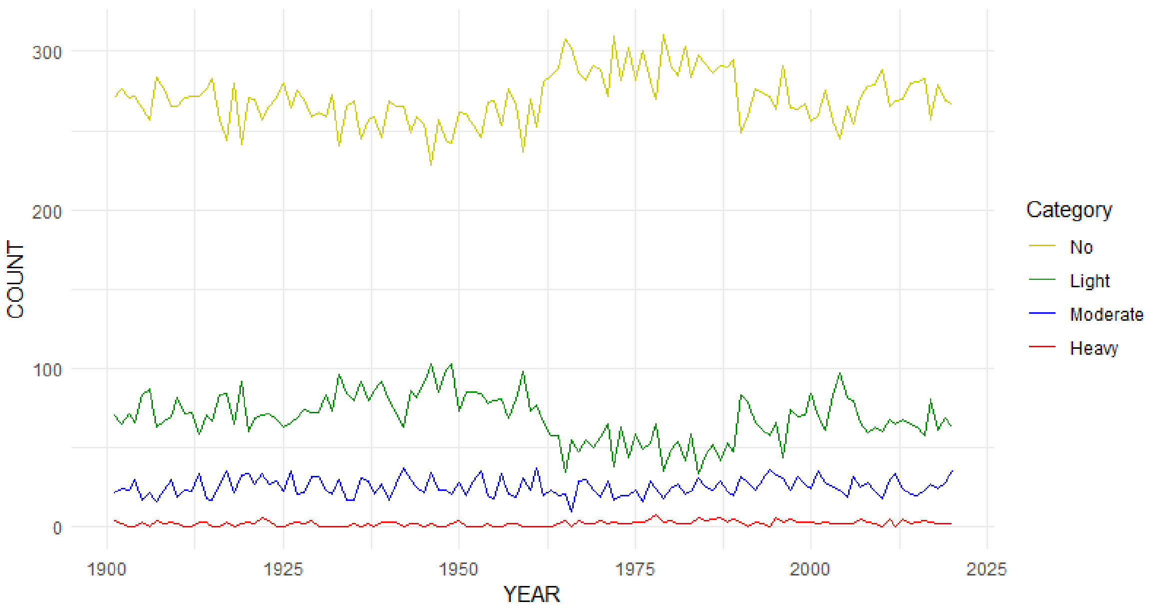


Figure 29: Yearly Plot of Different Intensities of Rainfall in Manbhum Purulia

Figure 33 and 34 show distribution of various intensities of rainfall over different months and seasons respectively. Maximum percentage of no rainfall days occurs in December (11.28%), then January (10.89%). Maximum percentage of no rainfall days (31.8%) occurs in Winter. Maximum percentage of light (71.21%), moderate (83.9%) and heavy (87.93%) rainfall days occurs in Monsoon. Also minimum percentage of light (5.25%), moderate (2.47%) and heavy (.08%) rainfall days occurs in Winter. These tell that most and least rainfall occurs in Monsoon and Winter respectively, which is very obvious from Figure 28 and real life observation.

Table 19 shows various descriptive statistics of various intensities of rainfall in various months in Manbhum Purulia. Table 20 shows similar for various seasons. From Table 19 and 20, it is seen that maximum average number of no (30.5167), light (14.1667) and moderate (6.5667) rainfall days occur in the months of December, August and July respectively. Maximum average number of no rainfall occurs in Winter (86.0417) and Monsoon experiences maximum average number of light (48.875) and moderate (20.6667) rainfall days, that is, Monsoon is the wetest and Winter is the driest season.

Figure 35 - 36 show yearly rainfall of different intensities in different months and seasons. Here also it is seen that more rainfall and more variability occur more or less together. From Figure 29 and 36, it is seen that patterns in various intensities of rainfall are more or less similar in yearly and Monsoon plot, which is obvious.

Appendix

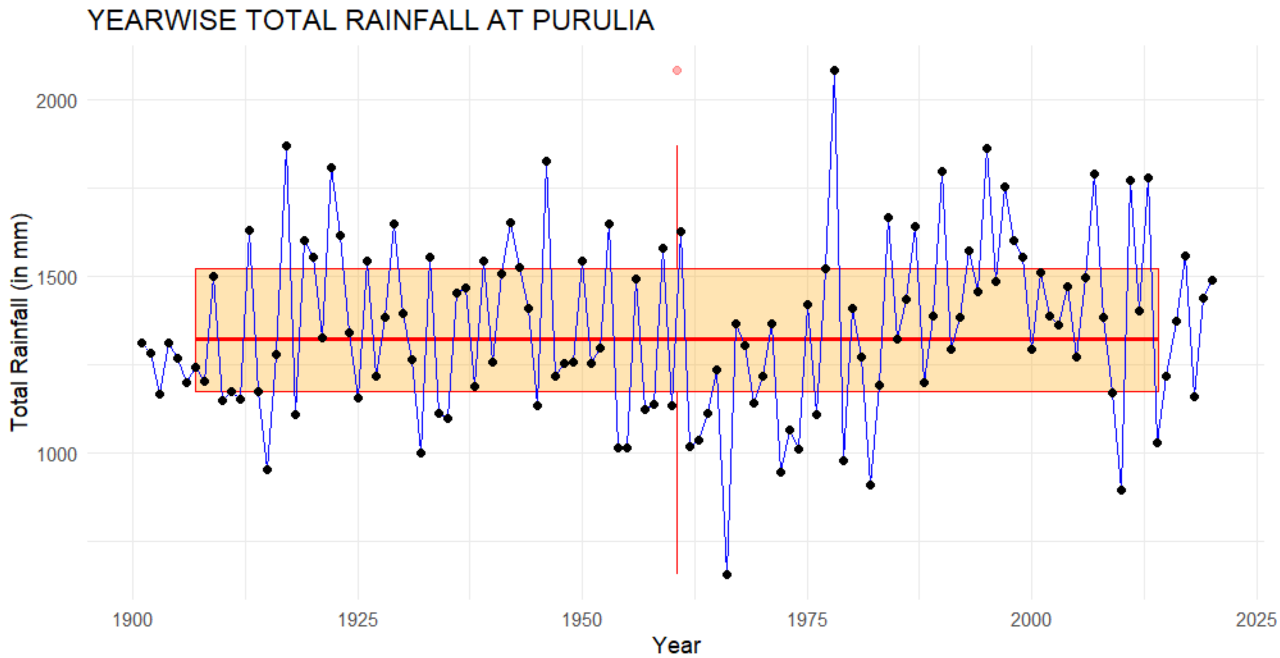


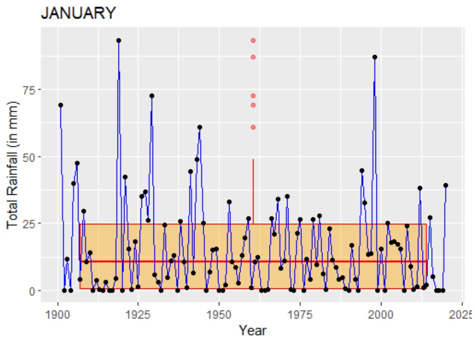
Figure 30: Yearly Rainfall in Manbhum Purulia

Table 17: Monthly Statistics of Rainfall in Manbhum Purulia

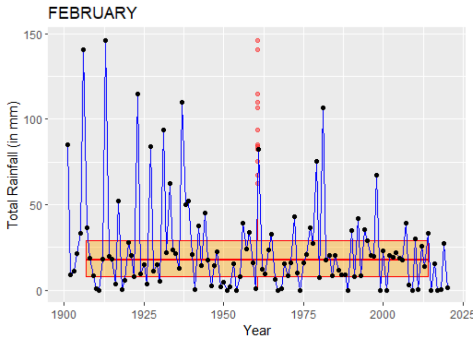
MONTH	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Jan	15.2723	18.3872	93.26 (1919)	0
Feb	24.5145	28.5294	146.06 (1913)	0
Mar	23.7349	26.9638	143.2474 (1998)	0
Apr	30.5445	28.9875	209.8 (1993)	0
May	68.2567	45.2329	303.88 (2013)	4.8 (1979)
Jun	218.3088	120.2428	842 (1984)	27.12 (1905)
Jul	316.1432	111.132	671.75 (1920)	91.34 (1966)
Aug	311.7862	95.6028	658.76 (1923)	141.7 (1973)
Sep	231.0788	105.3961	716.3 (1978)	46.6 (1966)
Oct	89.2483	81.3762	434.5967 (2013)	0
Nov	15.5781	25.6058	135 (1995)	0
Dec	6.2798	14.2825	87.1 (1991)	0

Table 18: Seasonal Statistics of Rainfall in Manbhum Purulia

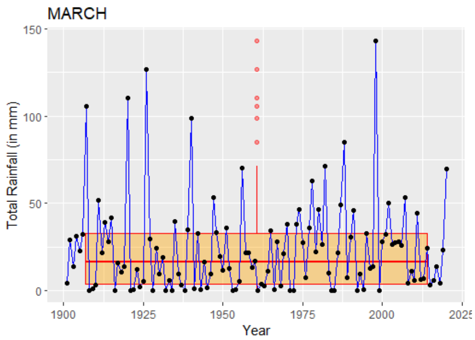
SEASON	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Pre-Monsoon	122.5361	61.1342	357.6857 (2013)	11.9 (1972)
Monsoon	1077.317	214.7234	1683.3 (1978)	553.86 (1966)
Post-Monsoon	104.8264	85.2552	434.5967 (2013)	0 (1907, 1918)
Winter	46.0667	38.3524	187.98 (1906)	0



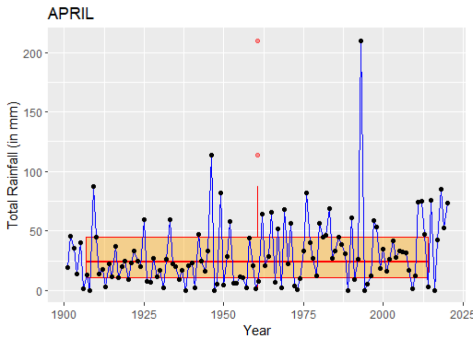
(a) January



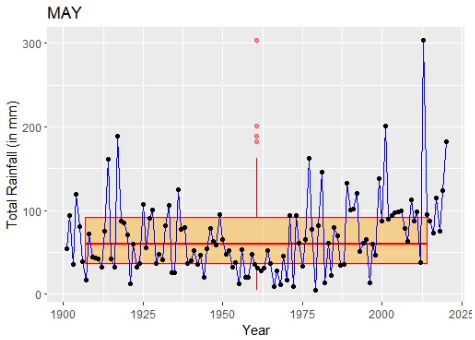
(b) February



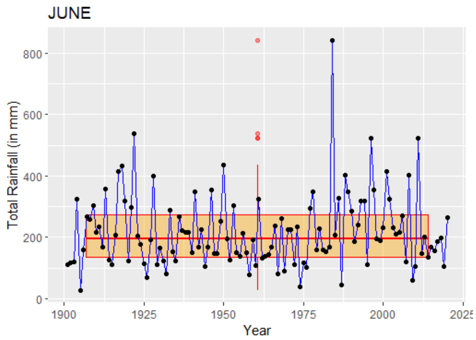
(c) March



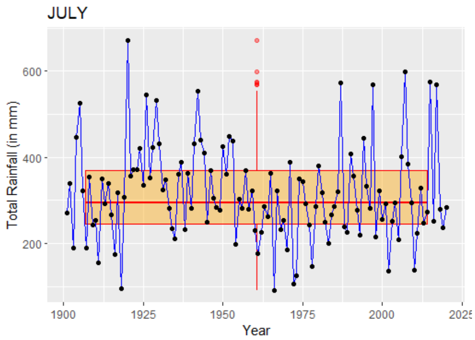
(d) April



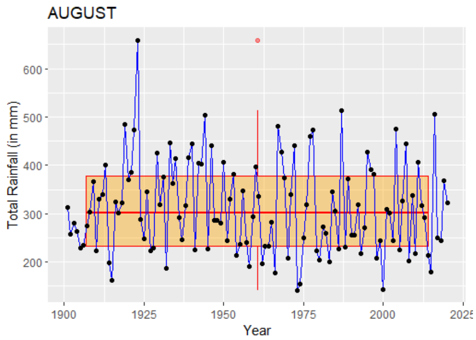
(e) May



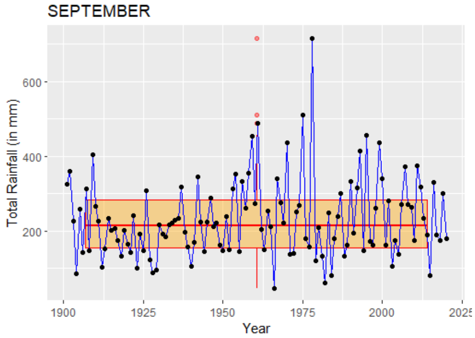
(f) June



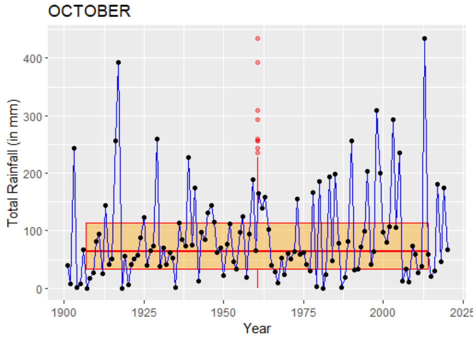
(g) July



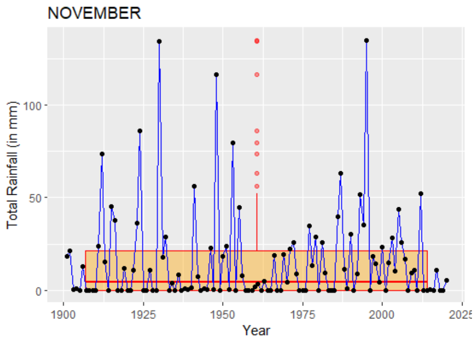
(h) August



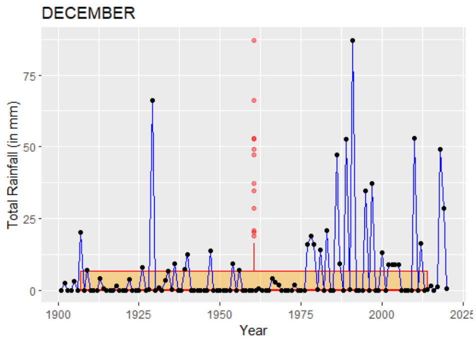
(i) September



(j) October

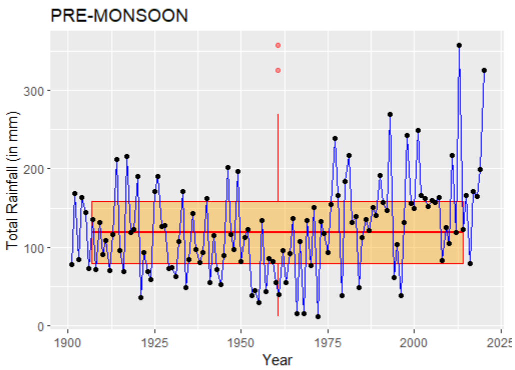


(k) November

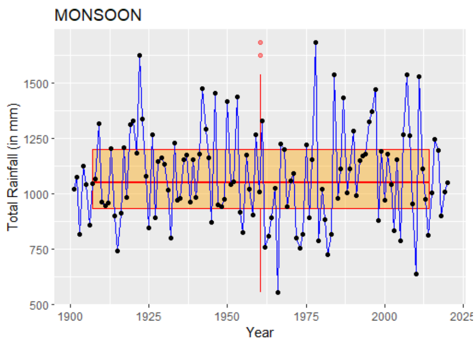


(l) December

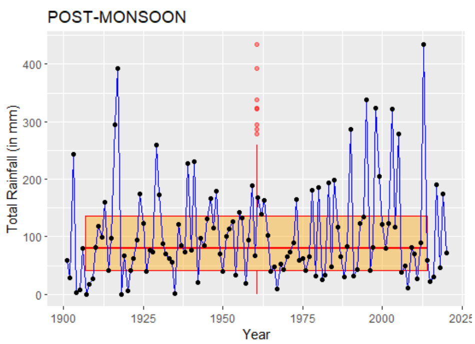
Figure 31: Monthly Rainfall in Manbhum Purulia



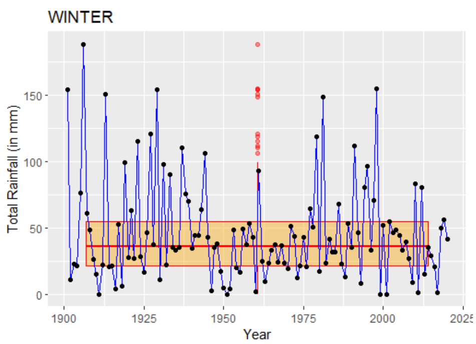
(a) Pre-Monsoon



(b) Monsoon

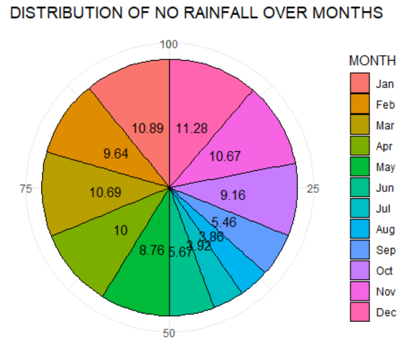


(c) Post-Monsoon

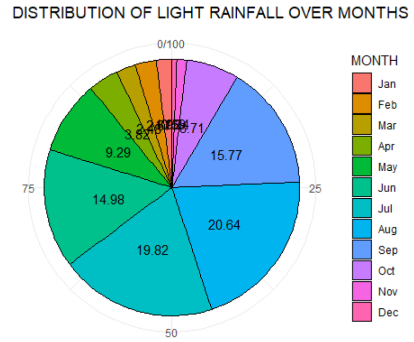


(d) Winter

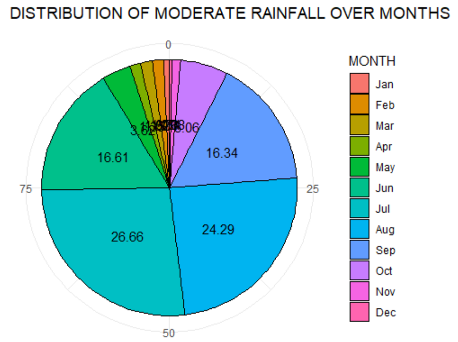
Figure 32: Seasonal Rainfall in Manbhum Purulia



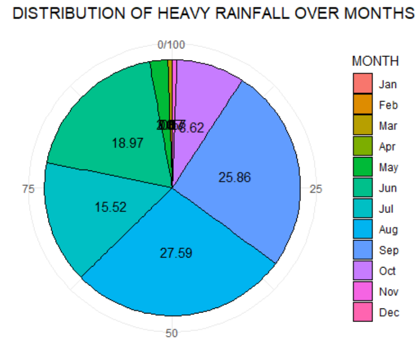
(a) No Rainfall



(b) Light Rainfall

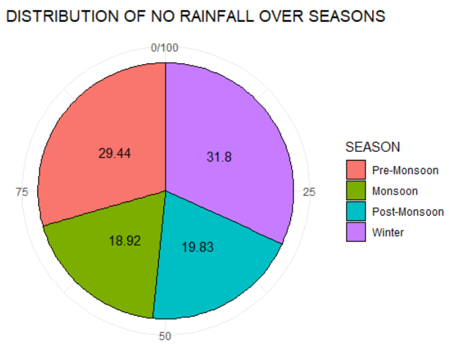


(c) Moderate Rainfall

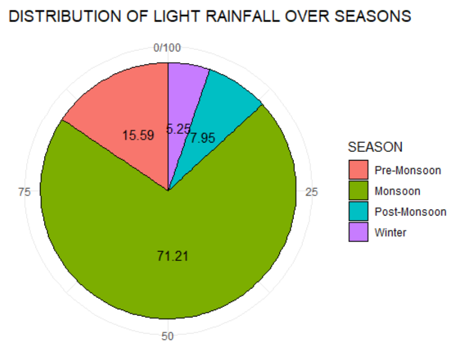


(d) Heavy Rainfall

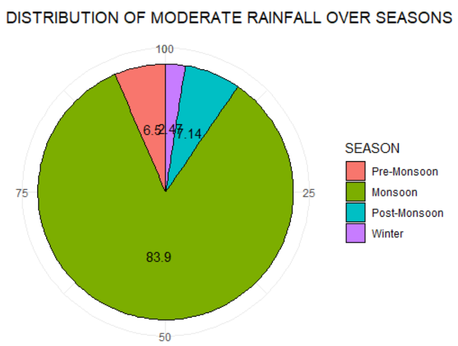
Figure 33: Distribution of Various Intensities of Rainfall over Months in Manbhum Purulia



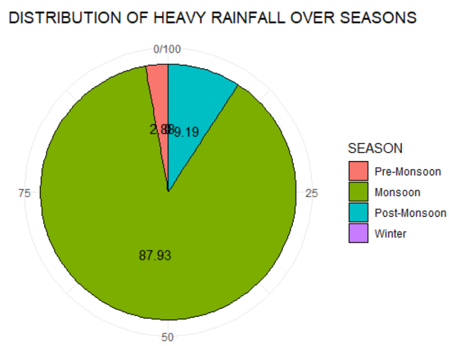
(a) No Rainfall



(b) Light Rainfall



(c) Moderate Rainfall



(d) Heavy Rainfall

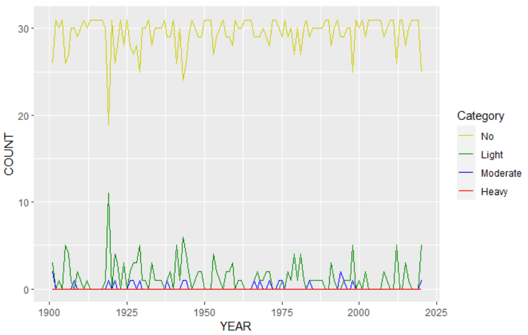
Figure 34: Distribution of Various Intensities of Rainfall over Seasons in Manbhum Purulia

Table 19: Monthly Statistics of Various Intensities Rainfall in Manbhum Purulia

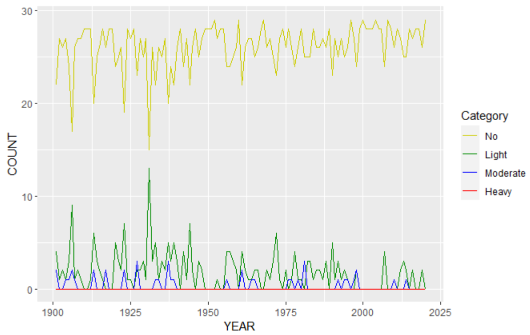
MONTH	STATISTICS	INTENSITY			
		NO	LIGHT	MODERATE	HEAVY
January	Mean	29.4583	1.3583	0.1833	0
	SD	1.91	1.7262	0.4278	0
	Maximum	31	11	2	0
	Minimum	19	0	0	0
February	Mean	26.0667	1.8333	0.35	0
	SD	2.4178	2.071	0.703	0
	Maximum	29	13	3	0
	Minimum	15	0	0	0
March	Mean	28.9167	1.7	0.375	0.0083
	SD	2.2382	1.8556	0.7078	0.0909
	Maximum	31	10	4	1
	Minimum	20	0	0	0
April	Mean	27.0417	2.625	0.3333	0
	SD	2.6121	2.4326	0.6625	0
	Maximum	30	14	4	0
	Minimum	15	0	0	0
May	Mean	23.7	6.375	0.8917	0.0333
	SD	5.8404	5.8879	1.1015	0.1795
	Maximum	31	31	5	1
	Minimum	0	0	0	0
June	Mean	15.35	10.2833	4.0917	0.275
	SD	4.6916	3.8712	2.8136	0.6578
	Maximum	27	22	13	4
	Minimum	5	2	0	0
July	Mean	10.6083	13.6	6.5667	0.225
	SD	4.5976	3.8306	2.9881	0.491
	Maximum	21	24	16	2
	Minimum	1	3	0	0
August	Mean	10.45	14.1667	5.9833	0.4
	SD	4.143	3.7977	2.5396	0.688
	Maximum	21	25	12	3
	Minimum	1	3	1	0
September	Mean	14.775	10.825	4.025	0.375
	SD	4.3425	3.7208	2.4882	0.696
	Maximum	26	22	14	3
	Minimum	4	3	0	0
October	Mean	24.775	4.6083	1.4917	0.125
	SD	3.9485	3.0531	1.6683	0.3778
	Maximum	31	14	10	2
	Minimum	13	0	0	0
November	Mean	28.875	0.85	0.2667	0.0083
	SD	1.6661	1.2952	0.6289	0.0909
	Maximum	30	7	3	1
	Minimum	20	0	0	0
December	Mean	30.5167	0.4083	0.075	0
	SD	1.0723	0.9174	0.3205	0
	Maximum	31	5	2	0
	Minimum	25	0	0	0

Table 20: Seasonal Statistics of Various Intensities Rainfall in Manbhum Purulia

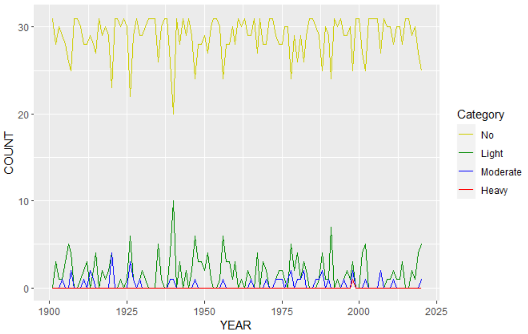
SEASON	STATISTICS	INTENSITY			
		NO	LIGHT	MODERATE	HEAVY
Pre-Monsoon	Mean	79.6583	10.7000	1.6000	0.0417
	SD	6.0463	6.0424	1.6093	0.1998
	Maximum	91	31	6	1
	Minimum	61	1	0	0
Monsoon	Mean	51.1833	48.8750	20.6667	1.2750
	SD	11.6919	10.2839	5.3281	1.3842
	Maximum	81	69	37	7
	Minimum	26	24	8	0
Post-Monsoon	Mean	53.6500	5.4583	1.7583	0.1333
	SD	4.3944	3.5116	1.6882	0.3859
	Maximum	61	16	10	2
	Minimum	40	0	0	0
Winter	Mean	86.0417	3.6000	0.6083	0.0000
	SD	3.4166	2.8763	0.9156	0.0000
	Maximum	91	14	4	0
	Minimum	75	0	0	0



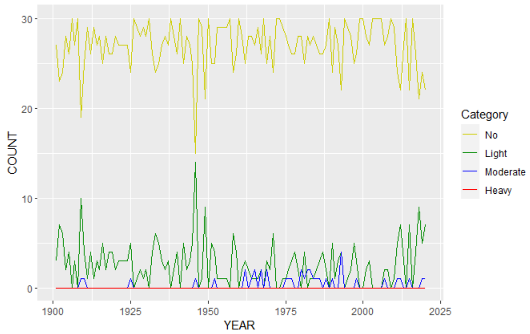
(a) January



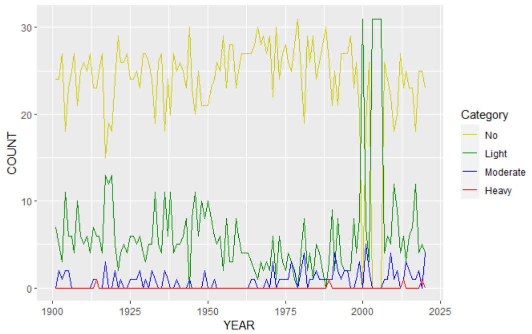
(b) February



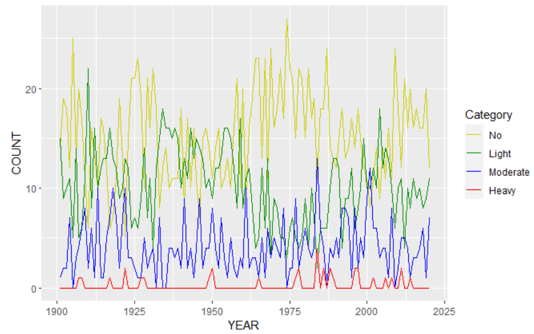
(c) March



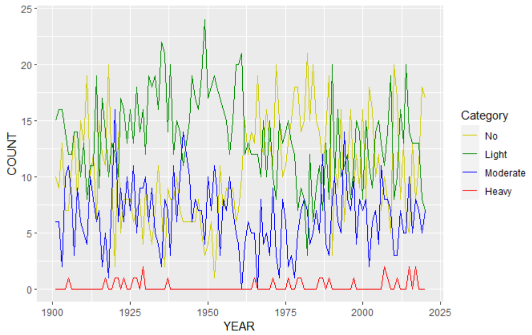
(d) April



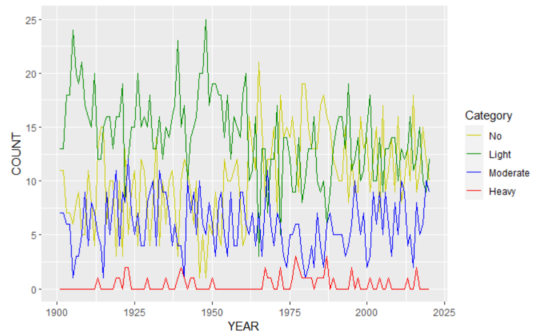
(e) May



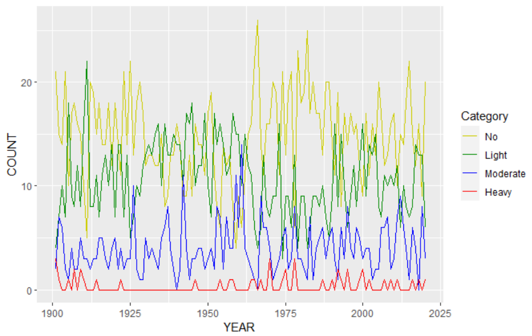
(f) June



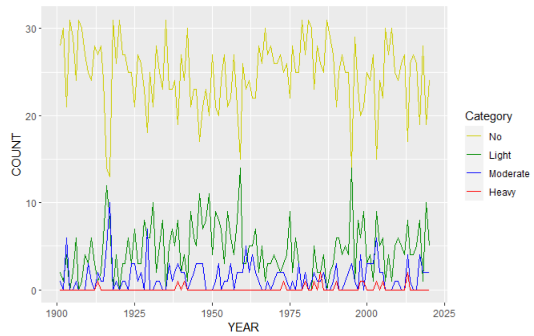
(g) July



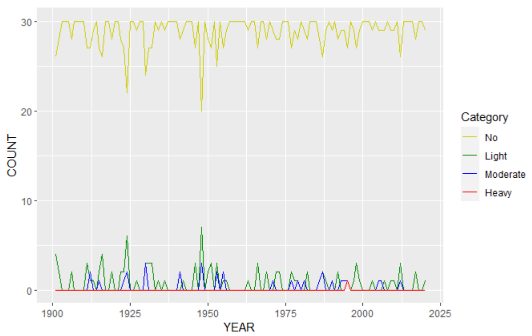
(h) August



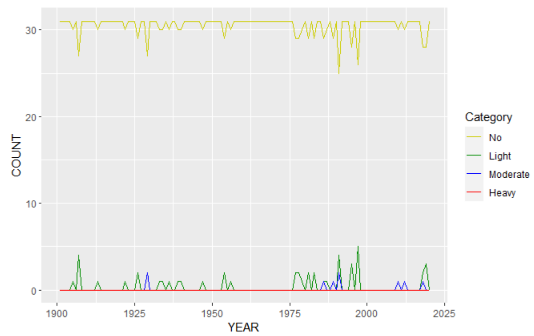
(i) September



(j) October

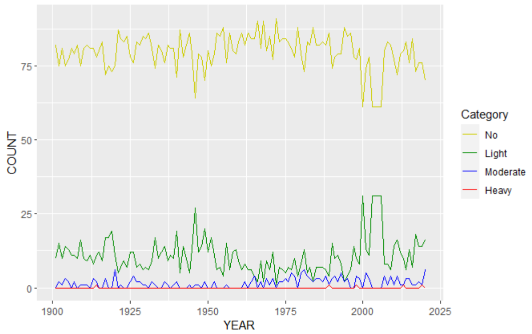


(k) November

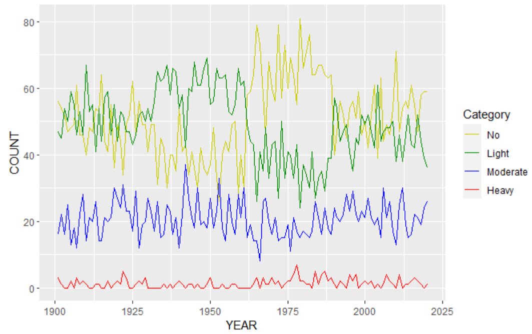


(l) December

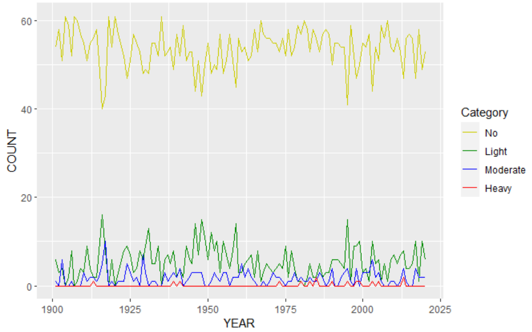
Figure 35: Monthwise Plot of Different Intensities of Rainfall in Manbhum Purulia



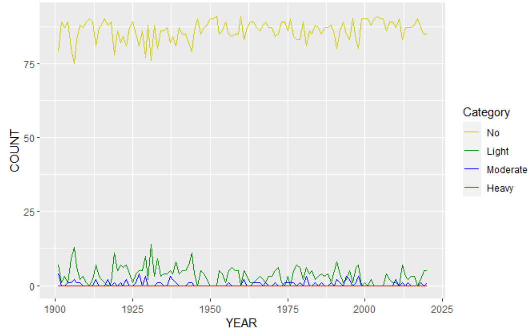
(a) Pre-Monsoon



(b) Monsoon



(c) Post-Monsoon



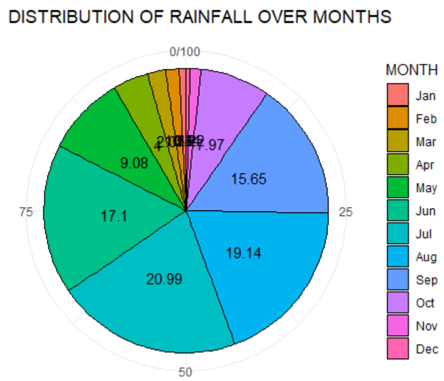
(d) Winter

Figure 36: Seasonwise Plot of Different Intensities of Rainfall in Manbhum Purulia

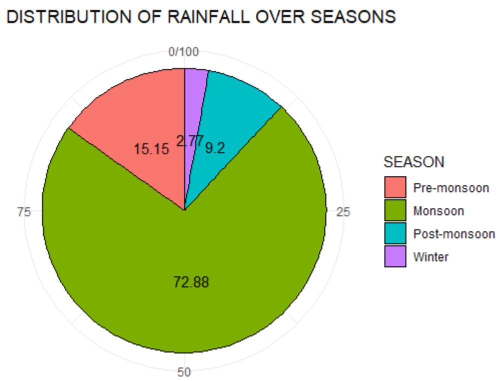
4.5 EDA for Nadia

In Figure 39, the yearly rainfall is plotted for 120 years. The yearly average rainfall in Nadia is 1313.007 mm with standard deviation 298.6616 mm. Year with highest (2219.967 mm) and lowest rainfall (532.2 mm) are 1953 and 1979 respectively. From Figure 39, it can be seen that there is a decreasing trend of rainfall in last two decades.

Figure 37 shows the distributions of rainfalls among various months and seasons. July receives maximum percentage (20.99%) of yearly rainfall, followed by August (19.14%). 72.88% of total rainfall occurs in Monsoon. Least percentage (2.77%) of total rainfall occurs in Winter.



(a) Monthwise



(b) Seasonwise

Figure 37: Monthwise and Seasonwise Distribution of Rainfall in Nadia

Table 22 shows various descriptive statistics of rainfall in various months in Nadia. Table 23 shows similar for various seasons. It is seen that year with highest annual rainfall is year of highest

June, October and Monsoon rainfall, which is 1953. Also year with lowest annual rainfall is year of lowest June and Monsoon rainfall, which is 1979.

Figure 40 - 41 show yearly rainfall and it's variation in different months and seasons. From Figure 39 and 41, it is seen that yearly and Monsoon rainfall patterns are similar as expected.

Table 21 shows various descriptive statistics of different intensities of yearly rainfall. Most of the days are no rainfall days in Nadia and event of heavy rainfall is rare. Maximum number of heavy rainfall has occurred in many years namely 1968, 1970, 1977, 2000.

Table 21: Statistics of Yearly Rainfall of Different Intensities in Nadia

Category	MEAN	SD	MAXIMUM	MINIMUM
No	274.3083	18.1185	330 (1976)	209 (1989)
Light	65.3917	17.6641	151 (1989)	21 (1979)
Moderate	23.9917	6.9456	45 (1953,1997)	5 (1989)
Heavy	1.5583	1.6623	6	0

In Figure 38, the yearly number of various categories of rainfall is plotted. From Figure 38, it can be seen that in the third quarter of previous century number of no rainfall and number of moderate rainfall days increased a little and number of light rainfall days decreased a little.

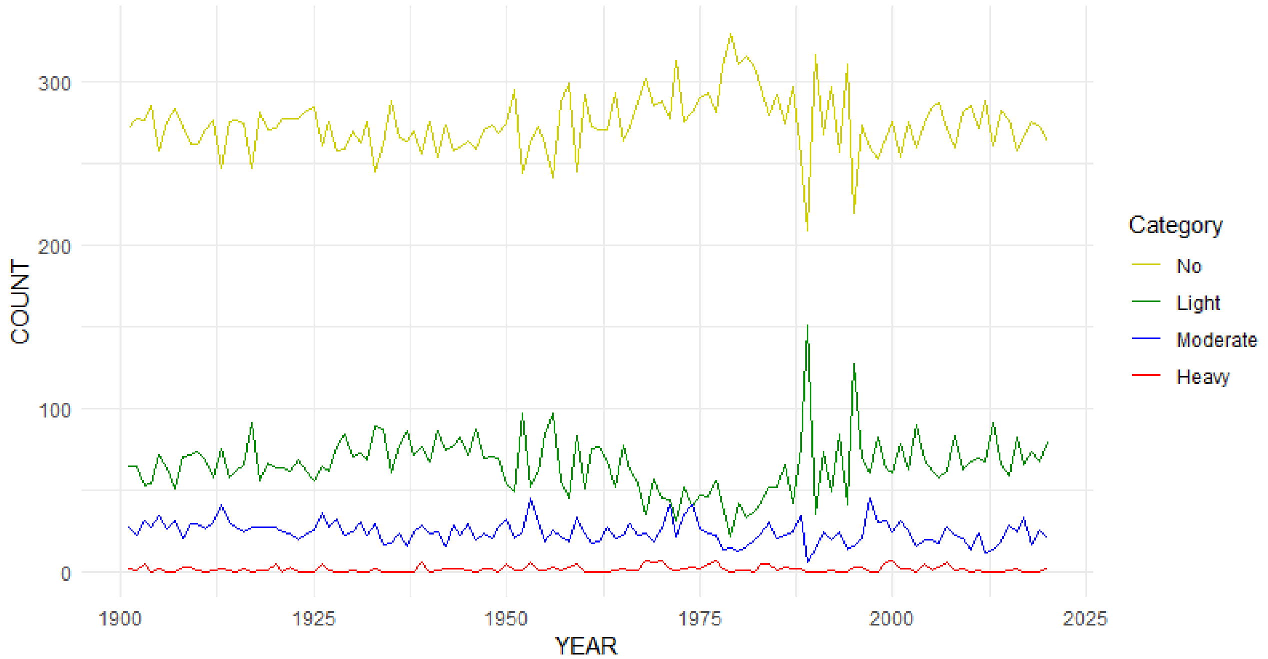


Figure 38: Yearly Plot of Different Intensities of Rainfall in Nadia

Figure 42 and 43 show distribution of various intensities of rainfall over different months and seasons respectively. Maximum percentage of no rainfall days occurs in December (11.15%), then January (10.93%). Maximum percentage of no rainfall days (31.75%) occurs in Winter. Maximum percentage of light (69.63%), moderate (72.63%) and heavy (81.29%) rainfall days occurs in Monsoon. Also minimum percentage of light (3.98%), moderate (2.26%) and heavy (5.53%) rainfall days occurs in Winter. These tell that most and least rainfall occurs in Monsoon and Winter respectively, which is very obvious from Figure 37 and real life observation.

Table 24 shows various descriptive statistics of various intensities of rainfall in various months in Nadia. Table 25 shows similar for various seasons. From Table 24 and 25, it is seen that maximum average number of no (30.5917), light (13.1917) and moderate (4.9250) rainfall days occur in the months of December, July and July respectively. Maximum average number of no rainfall occurs in Winter (87.1) and Monsoon experiences maximum average number of light (45.5333), moderate (17.425) and heavy (1.2667) rainfall days. These infer that Monsoon is the most wet and Winter is the driest season.

Figure 44 - 45 show yearly rainfall of different intensities in different months and seasons. Here also it is seen that more rainfall and more variability occur more or less together. From Figure 38 and 45, it is seen that patterns in various intensities of rainfall are more or less similar in yearly and Monsoon plot, which is obvious.

Appendix

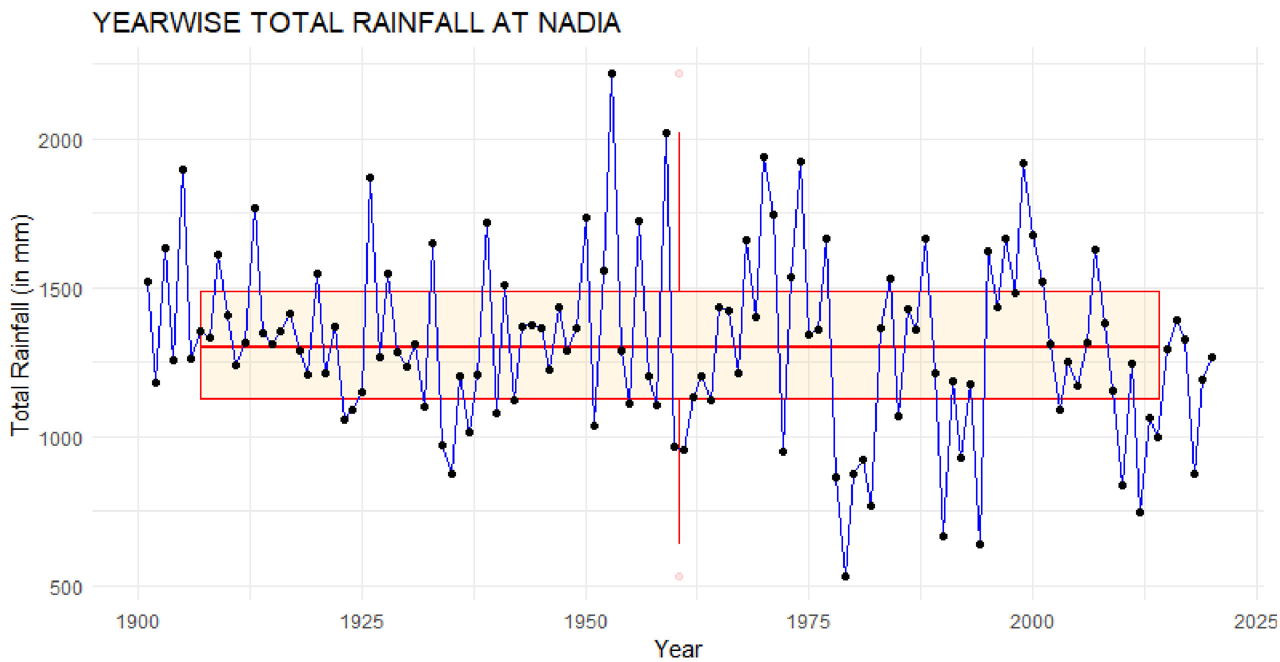


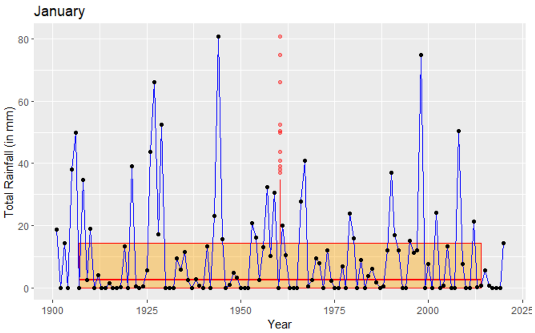
Figure 39: Yearly Rainfall in Nadia

Table 22: Monthly Statistics of Rainfall in Nadia

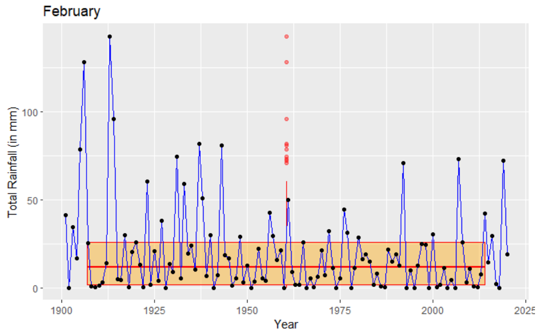
MONTH	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Jan	10.4976	16.0949	80.8 (1944)	0
Feb	20.1372	25.9796	142.6 (1913)	0
Mar	27.1603	33.0941	211.83 (1920)	0
Apr	52.5675	48.1919	244 (1971)	0
May	119.1817	64.7963	364.35 (2001)	0 (1990, 1994)
Jun	224.5207	100.269	523.8 (1953)	42.6 (1979)
Jul	275.6137	114.3678	667.6 (1968)	65.77 (1916)
Aug	251.3099	100.3967	577.17 (1909)	56.2 (1990)
Sep	205.4976	101.4794	591.8 (1970)	42.7 (1990)
Oct	104.6534	77.5281	419.7 (1953)	0
Nov	16.0801	29.3627	216.35 (1950)	0
Dec	5.7867	13.478	95.37 (1991)	0

Table 23: Seasonal Statistics of Rainfall in Nadia

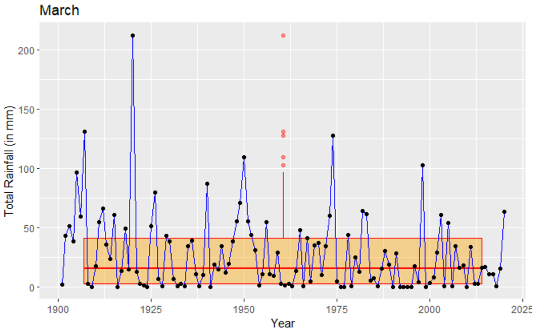
SEASON	MEAN	SD	MAXIMUM	MINIMUM
Pre-Monsoon	198.9096	93.0391	454.8 (1974)	0 (1990)
Monsoon	956.942	251.4215	1979.1 (1953)	410.7 (1979)
Post-Monsoon	120.7335	83.6487	423.15 (1959)	0 (1981,1994)
Winter	36.4215	35.019	178.05 (1906)	0



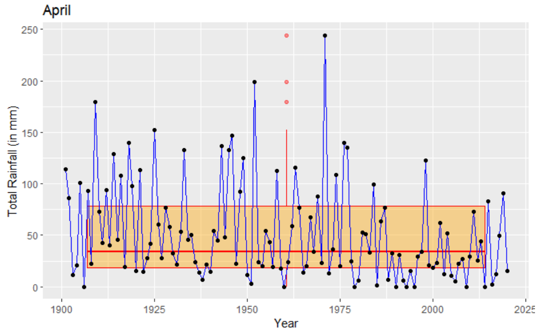
(a) January



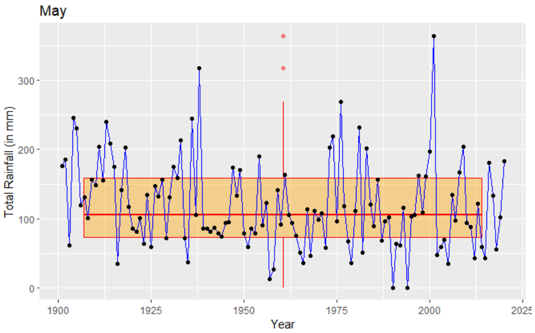
(b) February



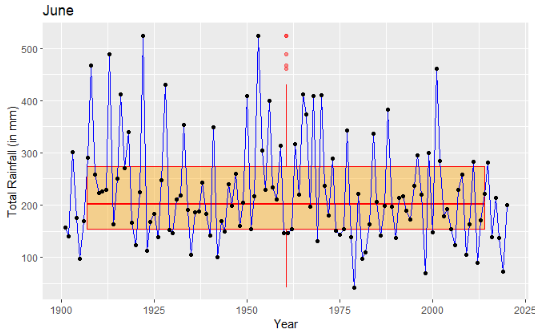
(c) March



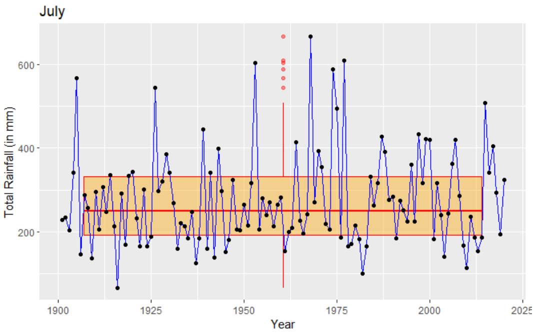
(d) April



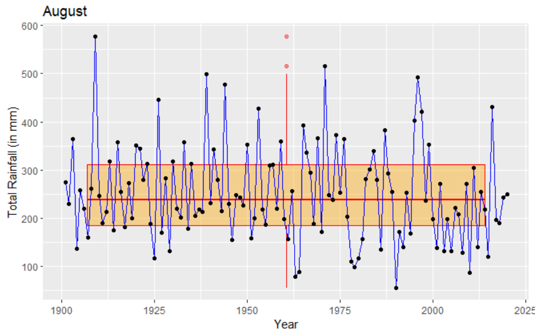
(e) May



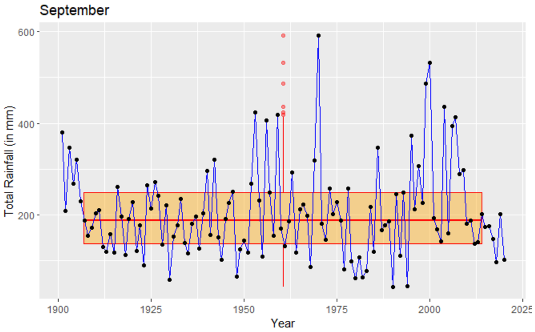
(f) June



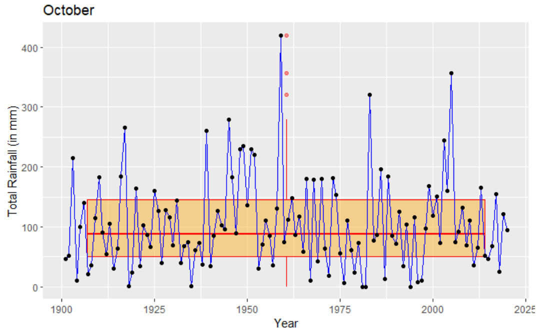
(g) July



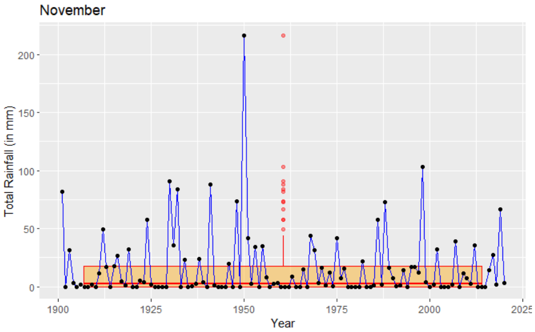
(h) August



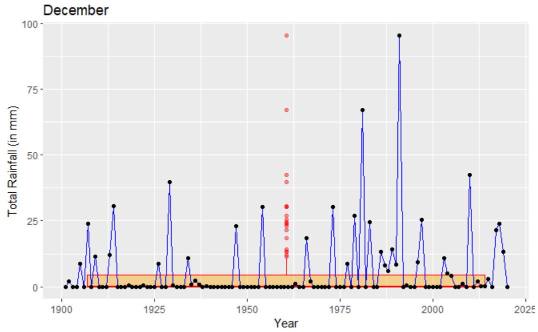
(i) September



(j) October

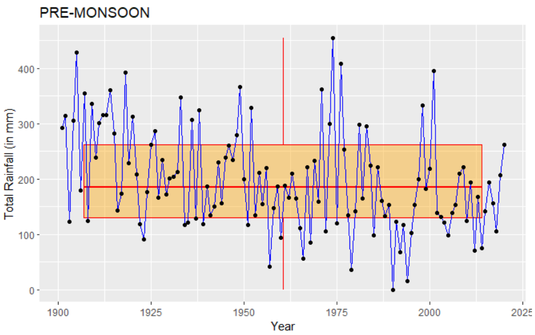


(k) November

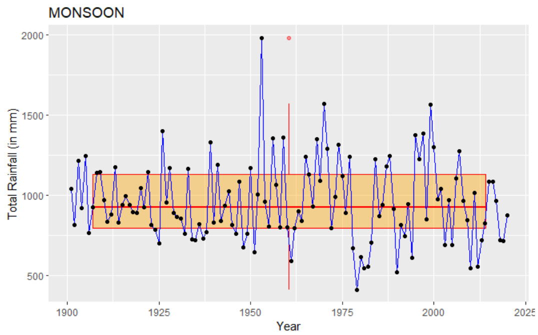


(l) December

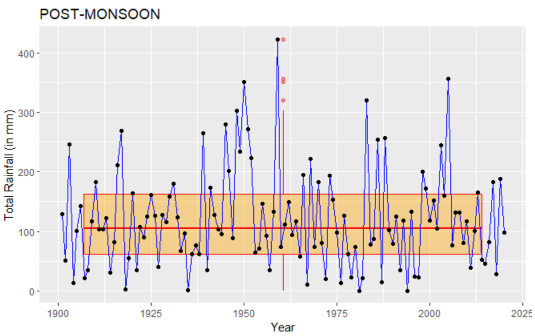
Figure 40: Monthly Rainfall in Nadia



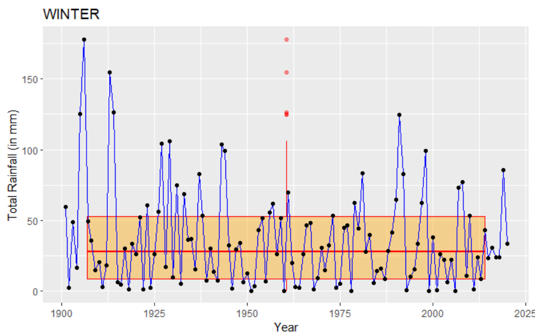
(a) Pre-Monsoon



(b) Monsoon

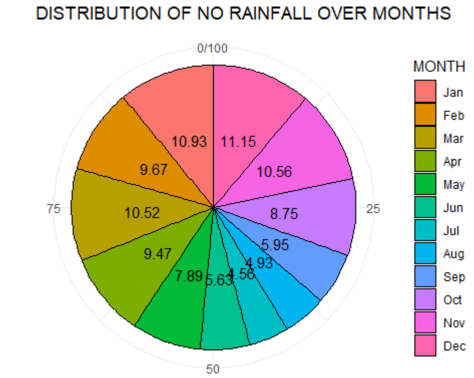


(c) Post-Monsoon

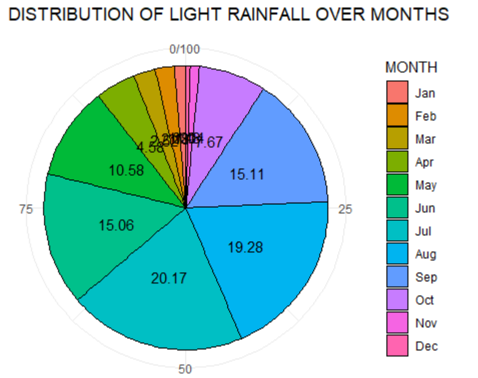


(d) Winter

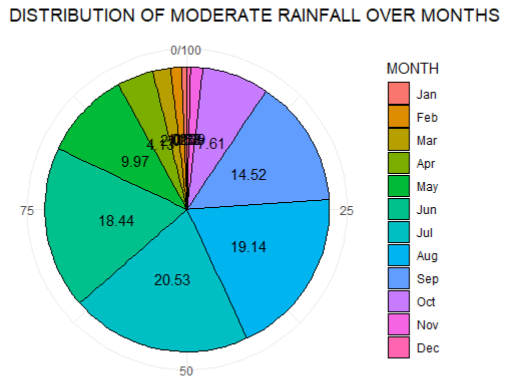
Figure 41: Seasonal Rainfall in Nadia



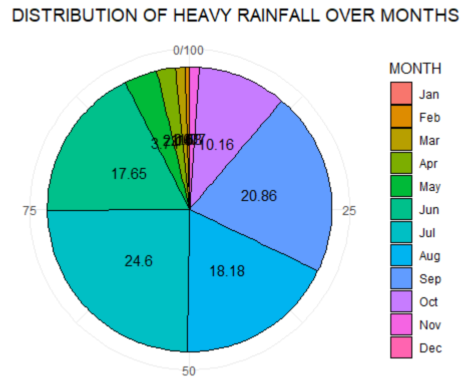
(a) No Rainfall



(b) Light Rainfall

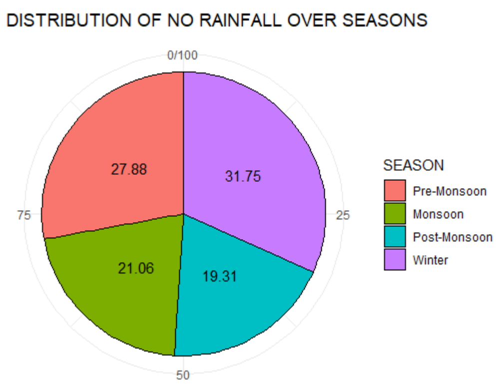


(c) Moderate Rainfall

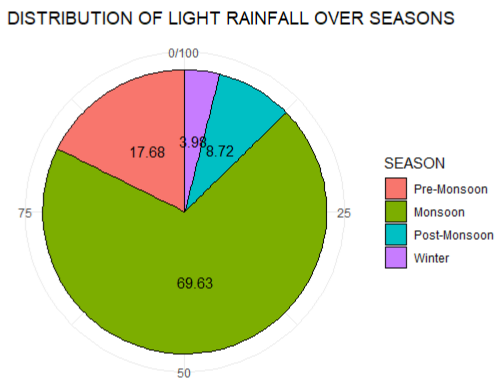


(d) Heavy Rainfall

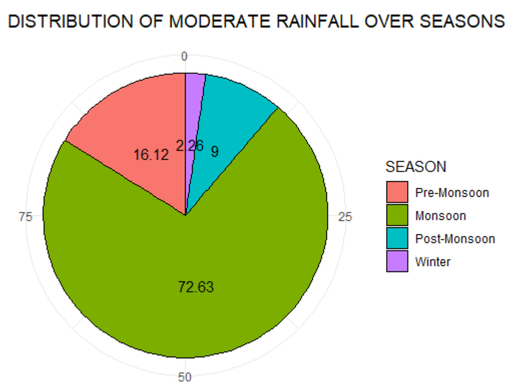
Figure 42: Distribution of Various Intensities of Rainfall over Months in Nadia



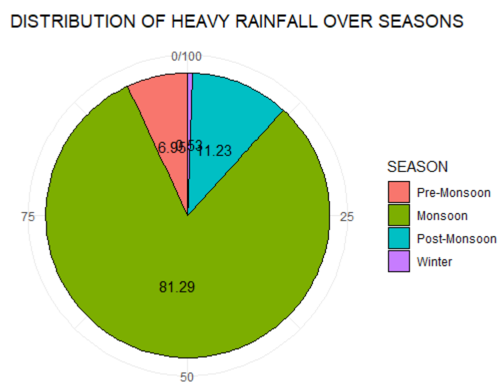
(a) No Rainfall



(b) Light Rainfall



(c) Moderate Rainfall



(d) Heavy Rainfall

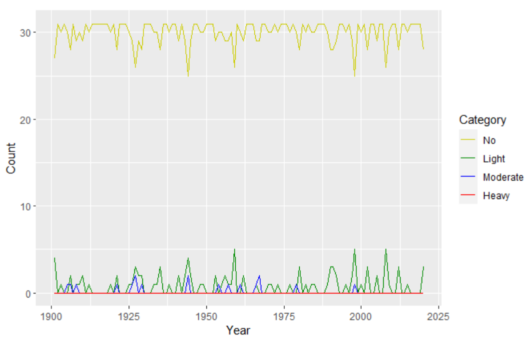
Figure 43: Distribution of Various Intensities of Rainfall over Seasons in Nadia

Table 24: Monthly Statistics of Various Intensities of Rainfall in Nadia

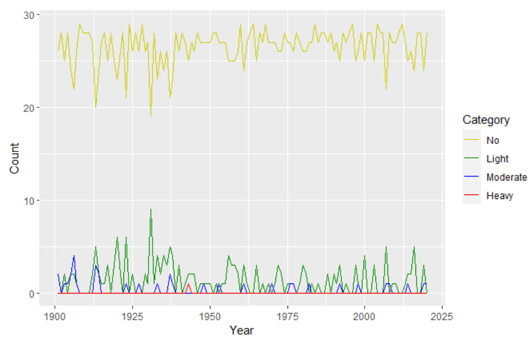
MONTH	STATISTICS	INTENSITY			
		NO	LIGHT	MODERATE	HEAVY
January	Mean	29.9917	0.8583	0.1500	0.0000
	SD	1.3632	1.2062	0.4213	0.0000
	Maximum	31	5	2	0
	Minimum	25	0	0	0
February	Mean	26.5167	1.4250	0.3000	0.0083
	SD	1.9450	1.6364	0.6532	0.0909
	Maximum	29	9	4	1
	Minimum	19	0	0	0
March	Mean	28.8500	1.6500	0.4833	0.0167
	SD	2.3225	1.9944	0.8061	0.1280
	Maximum	31	10	4	1
	Minimum	20	0	0	0
April	Mean	25.9833	2.9917	0.9917	0.0333
	SD	3.2274	2.6029	1.3693	0.1795
	Maximum	30	12	7	1
	Minimum	16	0	0	0
May	Mean	21.6333	6.9167	2.3917	0.0583
	SD	5.5901	5.5970	2.0384	0.2344
	Maximum	31	31	10	1
	Minimum	0	0	0	0
June	Mean	15.4500	9.8500	4.4250	0.2750
	SD	4.4419	3.9129	2.5254	0.6050
	Maximum	27	28	14	3
	Minimum	2	1	0	0
July	Mean	12.5000	13.1917	4.9250	0.3833
	SD	4.2934	4.2354	2.8959	0.7658
	Maximum	22	30	14	4
	Minimum	0	2	0	0
August	Mean	13.5167	12.6083	4.5917	0.2833
	SD	4.4083	4.1156	2.4375	0.6080
	Maximum	26	27	11	3
	Minimum	1	1	0	0
September	Mean	16.3083	9.8833	3.4833	0.3250
	SD	4.3681	4.0603	1.9621	0.7207
	Maximum	27	28	9	3
	Minimum	1	2	0	0
October	Mean	24.0000	5.0167	1.8250	0.1583
	SD	4.4926	3.9707	1.6666	0.4082
	Maximum	31	31	8	2
	Minimum	0	0	0	0
November	Mean	28.9667	0.6833	0.3333	0.0167
	SD	1.4941	1.1029	0.6625	0.1818
	Maximum	30	6	3	2
	Minimum	22	0	0	0
December	Mean	30.5917	0.3167	0.0917	0.0000
	SD	0.8316	0.7069	0.3161	0.0000
	Maximum	31	3	2	0
	Minimum	28	0	0	0

Table 25: Seasonal Statistics of Various Intensities of Rainfall in Nadia

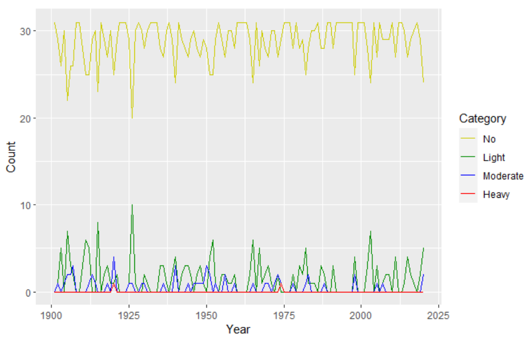
SEASON	STATISTICS	INTENSITY			
		NO	LIGHT	MODERATE	HEAVY
Pre-Monsoon	Mean	76.4667	11.5583	3.8667	0.1083
	SD	6.5038	6.2474	2.6924	0.3365
	Maximum	92	34	10	2
	Minimum	57	0	0	0
Monsoon	Mean	57.7750	45.5333	17.4250	1.2667
	SD	12.2130	12.0892	5.6342	1.4761
	Maximum	96	113	40	5
	Minimum	4	16	5	0
Post-Monsoon	Mean	52.9667	5.7000	2.1583	0.1750
	SD	4.7468	4.1324	1.8303	0.4409
	Maximum	61	31	9	2
	Minimum	30	0	0	0
Winter	Mean	87.1000	2.6000	0.5417	0.0083
	SD	2.5146	2.0632	0.8841	0.0909
	Maximum	91	9	5	1
	Minimum	81	0	0	0



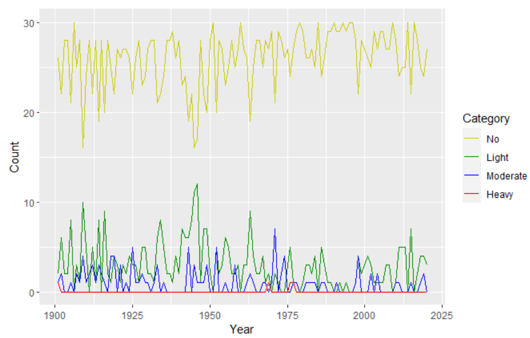
(a) January



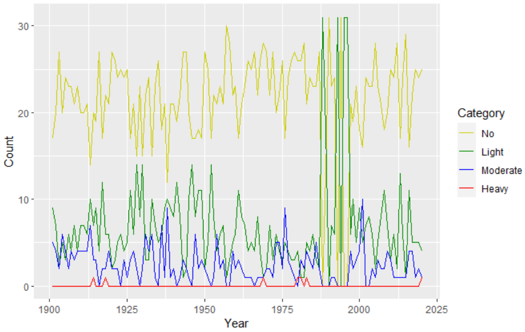
(b) February



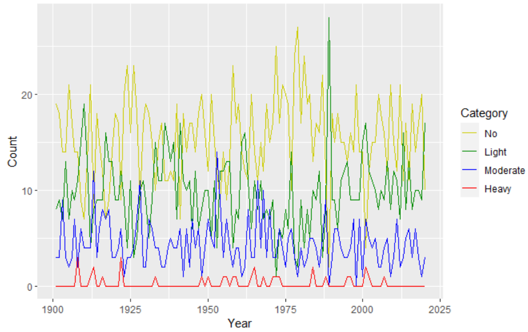
(c) March



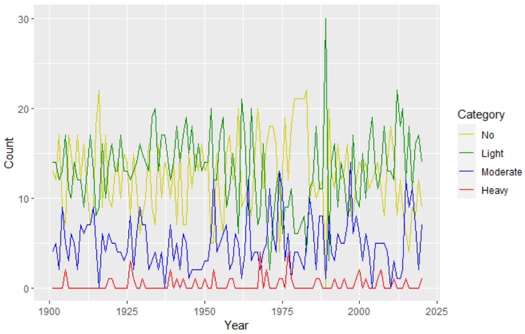
(d) April



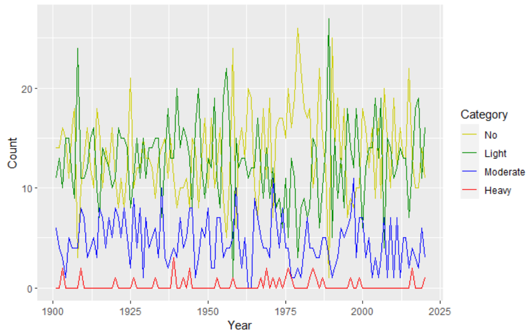
(e) May



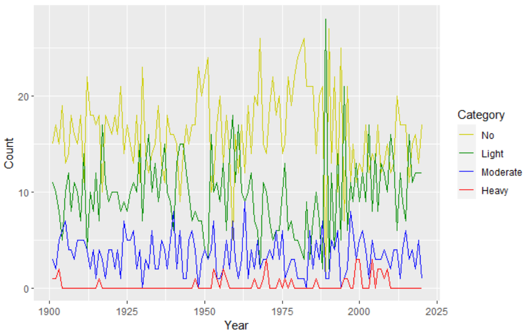
(f) June



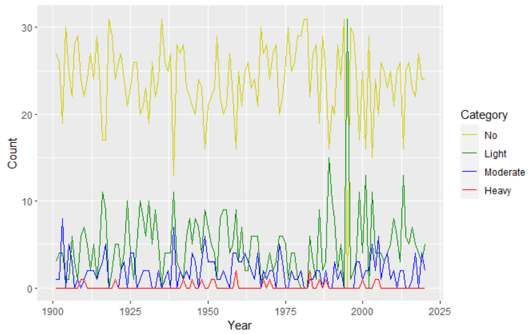
(g) July



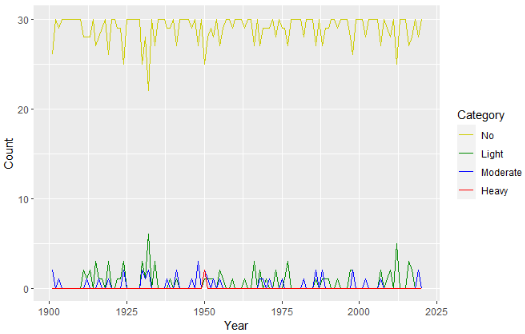
(h) August



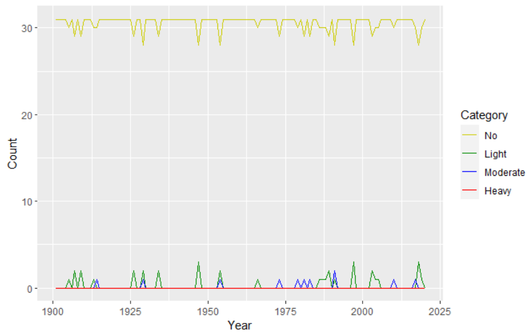
(i) September



(j) October

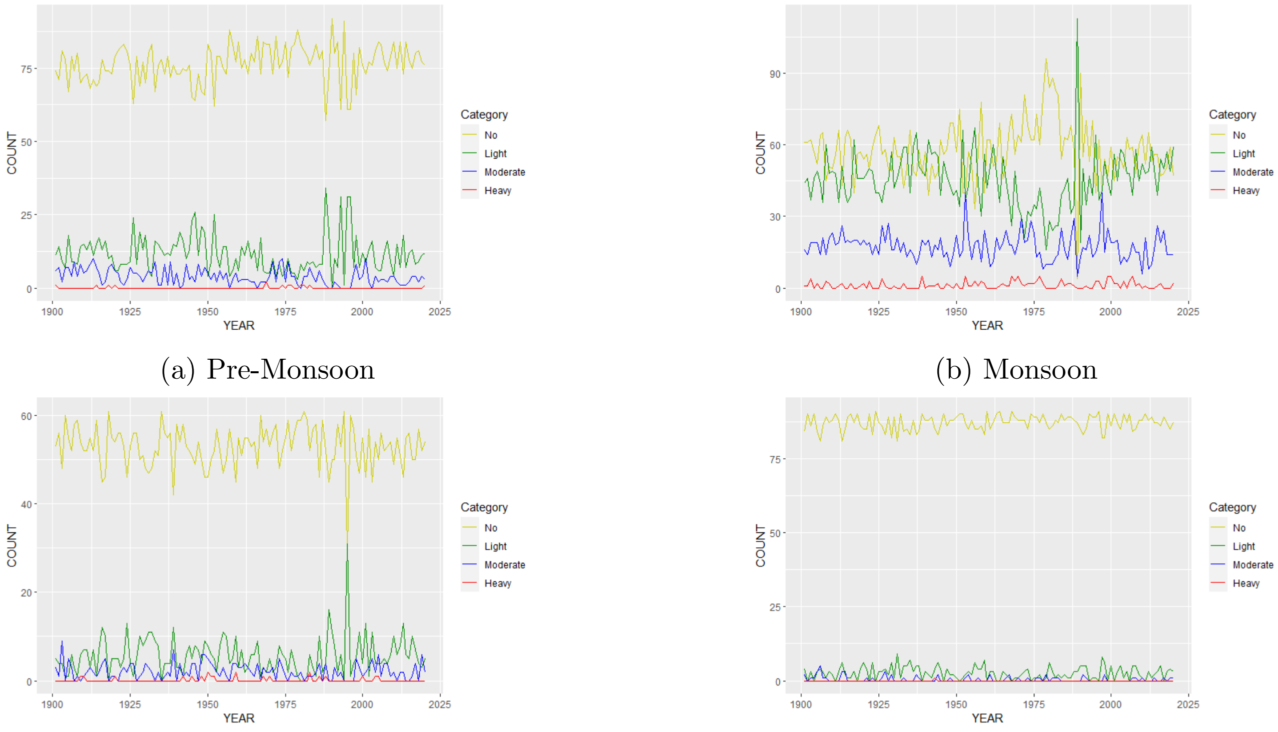


(k) November



(l) December

Figure 44: Monthwise Plot of Different Intensities of Rainfall in Nadia



(a) Pre-Monsoon (b) Monsoon

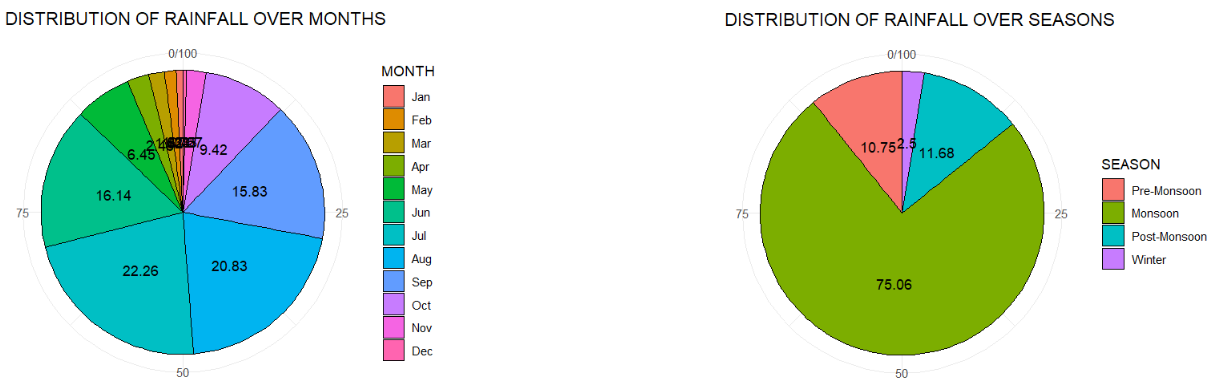
(c) Post-Monsoon (d) Winter

Figure 45: Seasonwise Plot of Different Intensities of Rainfall in Nadia

4.6 EDA for South 24 Parganas

In Figure 48, the yearly rainfall is plotted for 120 years. The yearly average rainfall in South 24 Parganas is 1768.882 mm with standard deviation 435.6788 mm. Year with highest (3677.583 mm) and lowest rainfall (1069.62 mm) are 1981 and 1935 respectively. From Figure 48, it can be seen that there is slight deficiency in rainfall in sixth to seventh decade. After that rainfall started to increase from middle of eighth decade and keep increasing till middle of last decade of previous century, then decreased till present.

Figure 46 shows the distributions of rainfalls among various months and seasons. July receives maximum percentage (22.26%) of yearly rainfall, followed by August (20.83%). 75.06% of total rainfall occurs in Monsoon. Least percentage (2.5%) of total rainfall occurs in Winter.



(a) Monthwise (b) Seasonwise

Figure 46: Monthwise and Seasonwise Distribution of Rainfall in South 24 Parganas

Table 27 shows various descriptive statistics of rainfall in various months in South 24 Parganas.

Table 28 shows similar for various seasons. It is seen that year with highest annual rainfall is year of highest June, December, Monsoon and Winter rainfall, which is 1981.

Figure 49 - 50 show yearly rainfall and it's variation in different months and seasons. It can be seen that greater amount of rainfall and greater variability more or less occur together. December shows very much uncertainty in monthly rainfall. From Figure 48 and 50, it is seen that yearly and Monsoon rainfall patterns are similar as expected.

Table 26 shows various descriptive statistics of different intensities of yearly rainfall. Most of the days are no rainfall days in South 24 Parganas and event of heavy rainfall is rare. Maximum number of heavy rainfall has occured in the year 1981, which is the year of highest rainfall.

Table 26: Statistics of Yearly Rainfall of Different Intensities in South 24 Parganas

CATEGORY	MEAN	SD	MAXIMUM (YEAR)	MINIMUM
No	260.3833	14.4304	307 (1979)	219 (1990)
Light	70.4417	13.6692	106 (1928)	31 (1972)
Moderate	31.35	7.3503	53 (1990, 1995)	17 (1979)
Heavy	3.075	2.9102	15 (1981)	0

Figure 47 shows yearly count of various intensities of rainfall.

From Figure 47, it can be seen that there is an decreasing trend of light rainfall days in sixth to seventh decade and then increasing trend. Also there is an decreasing trend of no rainfall days in middle of eighth to end of ninth of previous century.These give an idea similar as obtained from Figure 48.

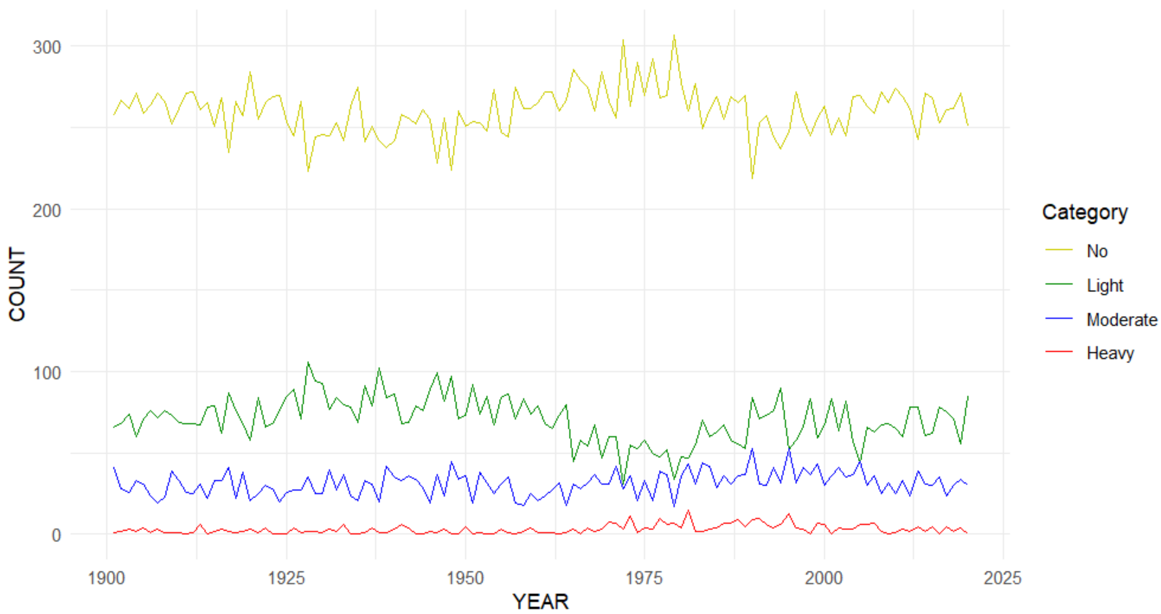


Figure 47: Yearly Plot of Different Intensities of Rainfall in South 24 Parganas

Figure 51 and 52 show distribution of various intensities of rainfall over different months and seasons respectively. Maximum percentage of no rainfall days occurs in January (11.72%), then December (11.45%). Maximum percentage of no rainfall days (33.31%) occurs in Winter. Maximum percentage of light (70.37%), moderate (76.05%) and heavy (77.51%) rainfall days occurs in Monsoon. Also minimum percentage of light (3.92%), moderate (2.34%) and heavy (1.08%) rainfall days occurs in Winter. These tell that most and least rainfall occurs in Monsoon and Winter respectively, which is very obvious from Figure 46 and real life observation.

Table 29 shows various descriptive statistics of various intensities of rainfall in various months in South 24 Parganas. Table 30 shows similar for various seasons. From Table 29 and 30, it is seen that maximum average number of no (30.525), light (13.8083), moderate (7.025) and heavy (0.575) rainfall days occur in the months of December, August, July and August respectively. Maximum average number of no rainfall occurs in Winter (86.725) and Monsoon experiences maximum average number of light (49.5667), moderate (23.8417) and heavy (2.3833) rainfall days. These infer that Monsoon is the most wet and Winter is the driest season.

Figure 53 - 54 show yearly rainfall of different intensities in different months and seasons. Here also it is seen that more rainfall and more variability occur more or less together. From Figure 47 and 54, it is seen that patterns in various intensities of rainfall are more or less similar in yearly and Monsoon plot, which is obvious.

Appendix

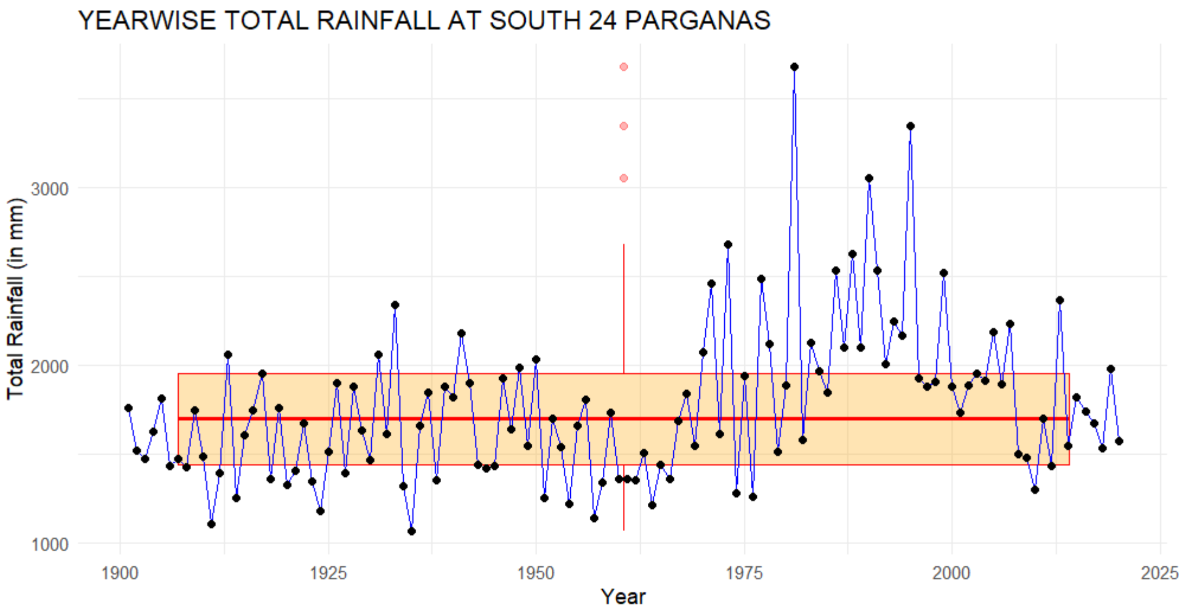


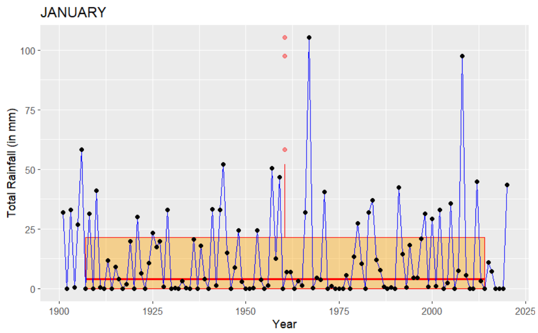
Figure 48: Yearly Rainfall in South 24 Parganas

Table 27: Monthly Statistics of Rainfall in South 24 Parganas

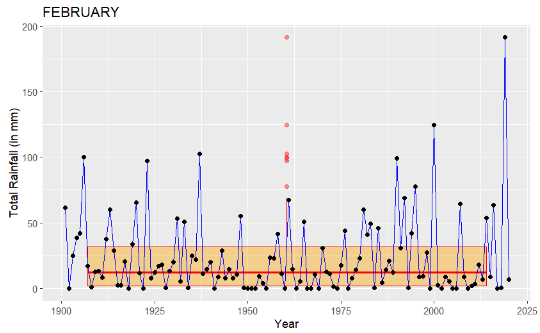
MONTH	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Jan	13.2051	18.8229	105.225 (1967)	0
Feb	23.4473	30.3848	191.3 (2019)	0
Mar	32.1796	51.5401	385.325 (1990)	0
Apr	43.9461	38.8418	226.3 (1971)	0 (2014)
May	114.0707	84.8346	613.325 (1995)	2.65 (1979)
Jun	285.5218	156.0904	1029.8 (1981)	33.5667 (1905)
Jul	393.6708	154.4072	811.85 (2015)	144.075 (1916)
Aug	368.5078	125.0482	685.9171 (2013)	178.0917 (2000)
Sep	280.1006	122.8814	886.85 (1986)	94.015 (1923)
Oct	166.5666	109.1943	532.7617 (2005)	6.75 (1997)
Nov	40.0673	58.1453	312.8 (1995)	0
Dec	7.598	22.7676	183.8833 (1981)	0

Table 28: Seasonal Statistics of Rainfall in South 24 Parganas

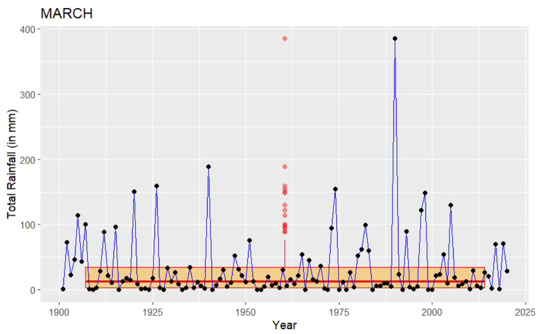
SEASON	MEAN	SD	MAXIMUM (YEAR)	MINIMUM (YEAR)
Pre-Monsoon	190.1964	113.0194	772.125 (1990)	23.25 (1972)
Monsoon	1327.8011	323.5395	2843.35 (1981)	783.85 (1976)
Post-Monsoon	206.6339	131.2016	628.7417 (1995)	9.4 (1914)
Winter	44.2505	41.3488	254.2333 (1981)	0 (1974, 2006)



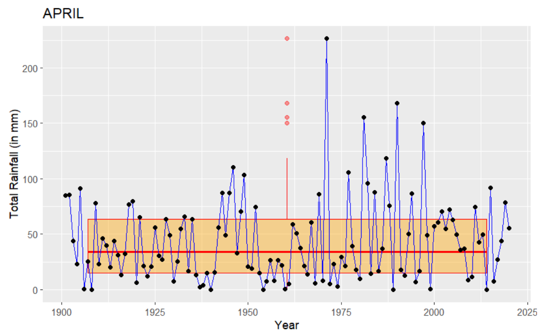
(a) January



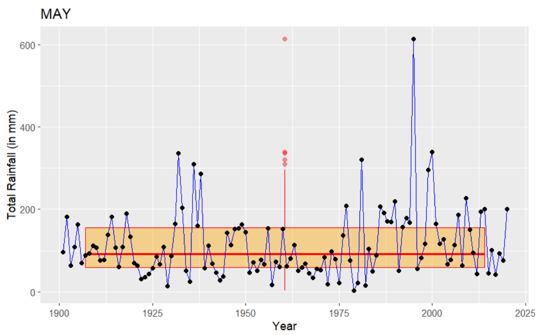
(b) February



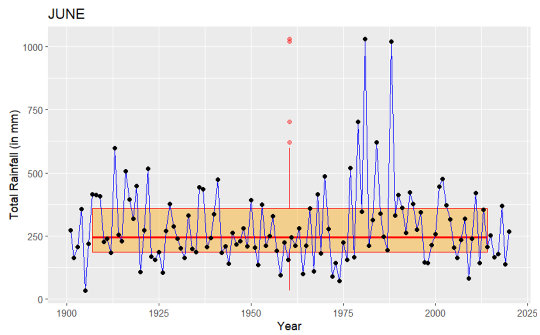
(c) March



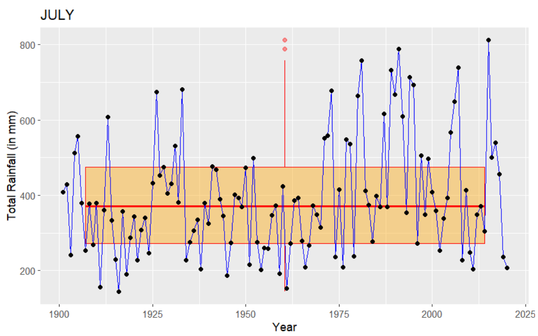
(d) April



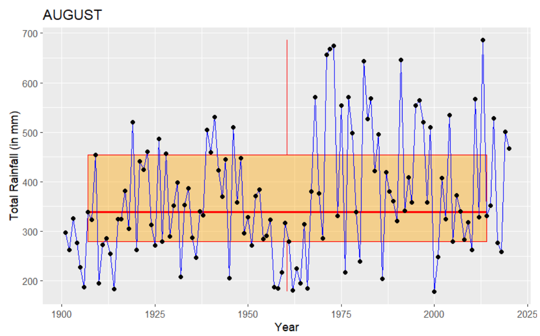
(e) May



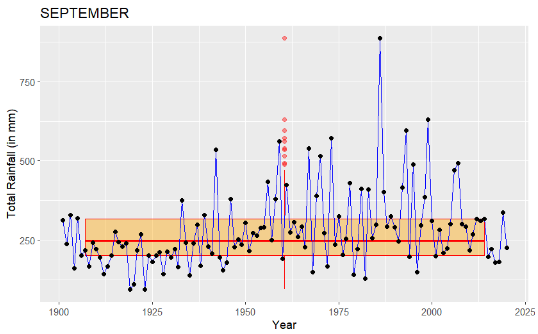
(f) June



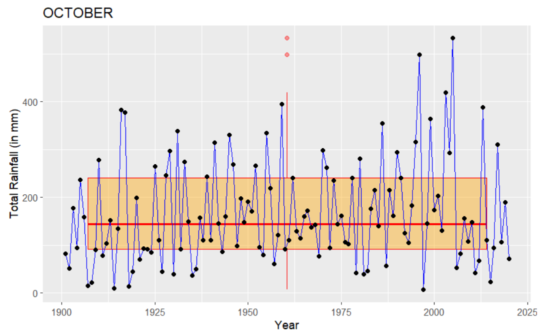
(g) July



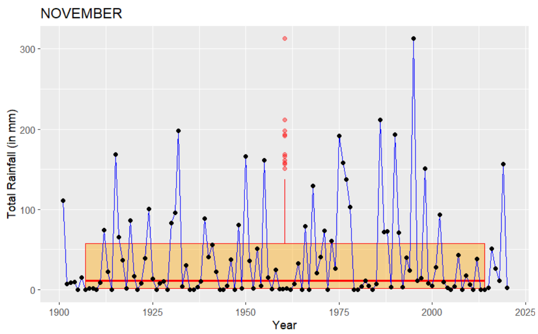
(h) August



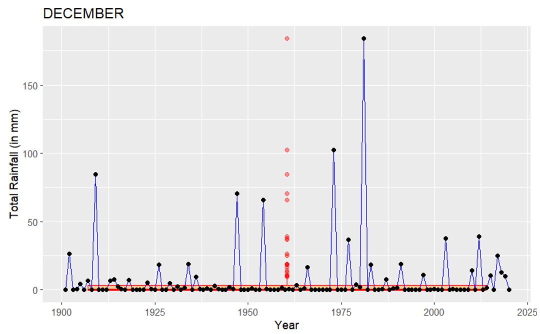
(i) September



(j) October

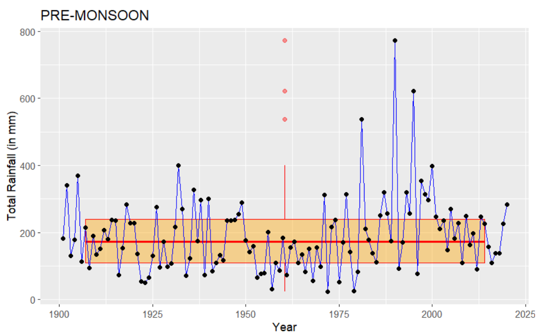


(k) November

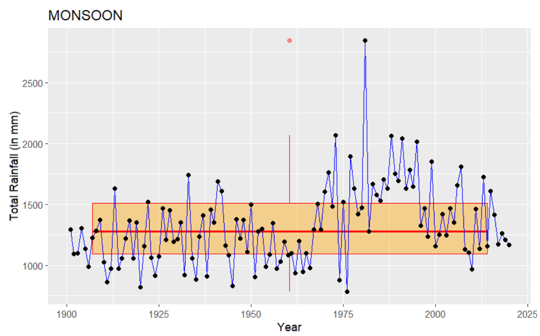


(l) December

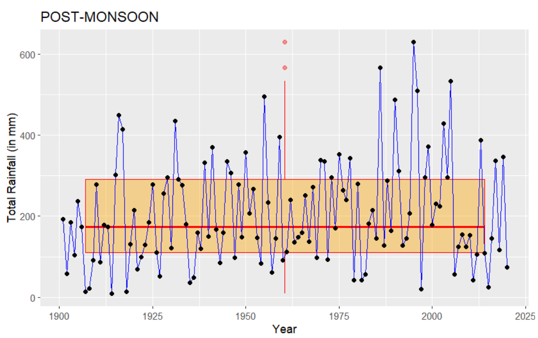
Figure 49: Monthly Rainfall in South 24 Parganas



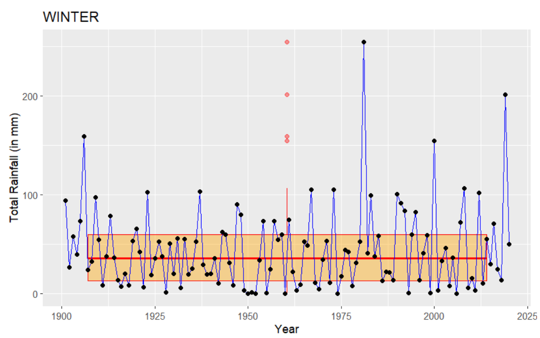
(a) Pre-Monsoon



(b) Monsoon

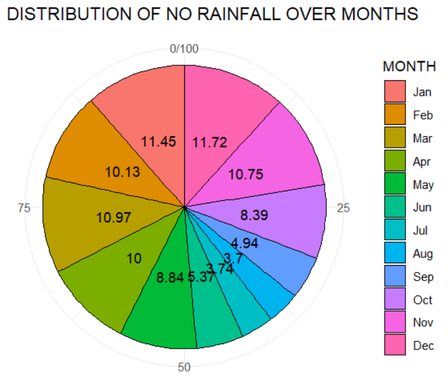


(c) Post-Monsoon

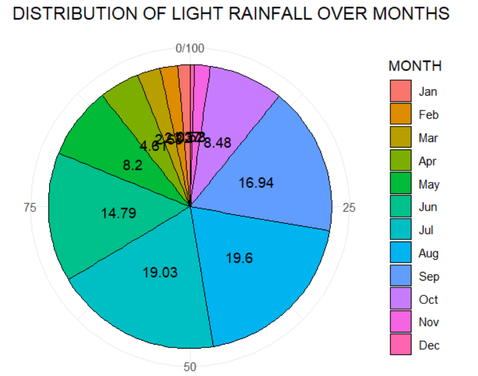


(d) Winter

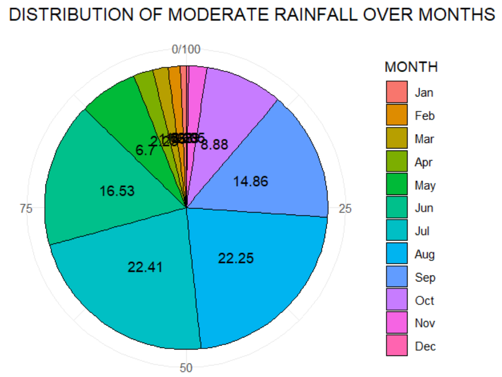
Figure 50: Seasonal Rainfall in South 24 Parganas



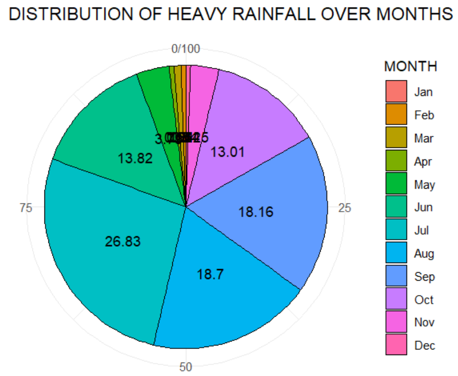
(a) No Rainfall



(b) Light Rainfall

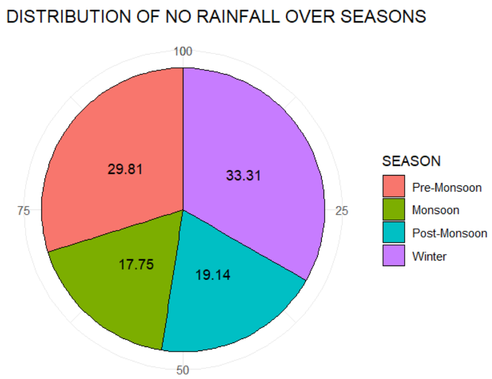


(c) Moderate Rainfall

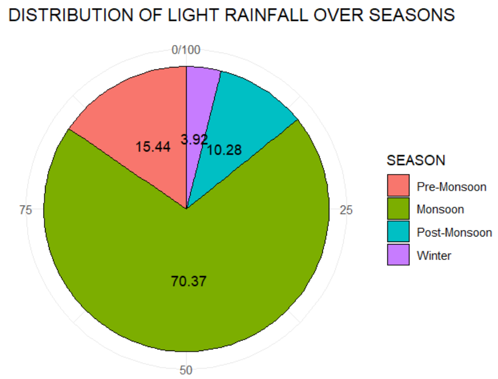


(d) Heavy Rainfall

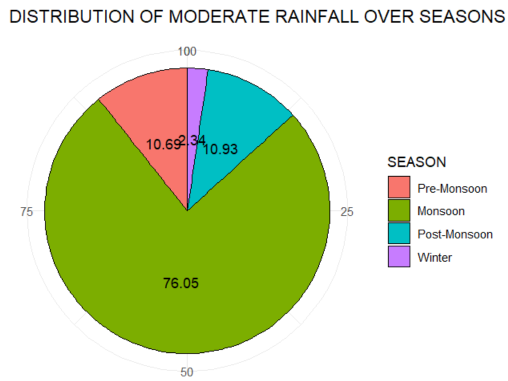
Figure 51: Distribution of Various Intensities of Rainfall over Months in South 24 Parganas



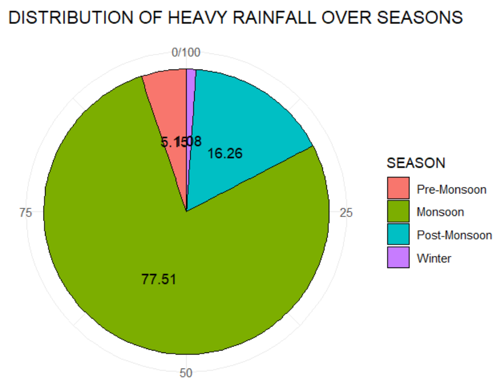
(a) No Rainfall



(b) Light Rainfall



(c) Moderate Rainfall



(d) Heavy Rainfall

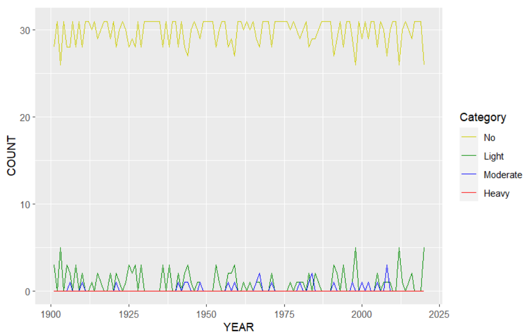
Figure 52: Distribution of Various Intensities of Rainfall over Seasons in South 24 Parganas

Table 29: Monthly Statistics of Various Intensities Rainfall in South 24 Parganas

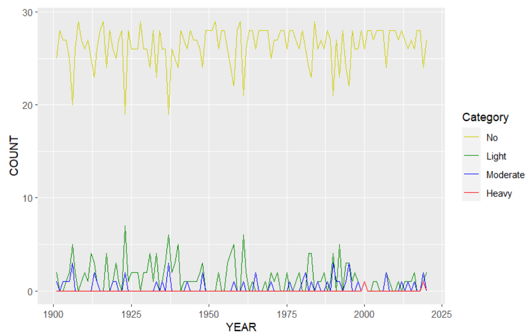
MONTH	STATISTICS	NO	LIGHT	MODERATE	HEAVY
January	Mean	29.825	0.9667	0.2083	0
	SD	1.4472	1.272	0.4983	0
	Maximum	31	5	3	0
	Minimum	26	0	0	0
February	Mean	26.375	1.425	0.4333	0.0167
	SD	2.0699	1.5741	0.7498	0.128
	Maximum	29	7	3	1
	Minimum	19	0	0	0
March	Mean	28.575	1.85	0.55	0.025
	SD	2.0699	2.0316	1.1751	0.2026
	Maximum	31	12	6	2
	Minimum	15	0	0	0
April	Mean	26.0333	3.25	0.7	0.0167
	SD	3.063	2.5828	1.1518	0.128
	Maximum	30	13	8	1
	Minimum	16	0	0	0
May	Mean	23.0083	5.775	2.1	0.1167
	SD	3.8243	3.1211	1.8046	0.4862
	Maximum	31	15	9	4
	Minimum	10	0	0	0
June	Mean	13.975	10.4167	5.1833	0.425
	SD	4.3079	3.4655	2.6925	0.8432
	Maximum	24	22	12	4
	Minimum	3	4	0	0
July	Mean	9.7417	13.4083	7.025	0.825
	SD	3.6297	3.5695	3.0372	1.1738
	Maximum	20	22	16	5
	Minimum	1	5	2	0
August	Mean	9.6417	13.8083	6.975	0.575
	SD	3.7943	3.5691	2.9537	0.8724
	Maximum	20	22	14	4
	Minimum	2	6	1	0
September	Mean	12.85	11.9333	4.65836	0.5583
	SD	3.6163	3.6872	2.2004	0.9556
	Maximum	22	21	11	4
	Minimum	5	4	0	0
October	Mean	21.8417	5.975	2.7833	0.4
	SD	4.5092	3.4192	2.0501	0.7
	Maximum	30	17	8	3
	Minimum	9	0	0	0
November	Mean	27.9917	1.2667	0.6417	0.1
	SD	2.0996	1.3707	1.11655	0.3266
	Maximum	30	9	5	2
	Minimum	20	0	0	0
December	Mean	30.525	0.3667	0.0917	0.0167
	SD	0.9125	0.763	0.3651	0.128
	Maximum	31	4	2	1
	Minimum	27	0	0	0

Table 30: Seasonal Statistics of Various Intensities Rainfall in South 24 Parganas

SEASON	STATISTICS	NO	LIGHT	MODERATE	HEAVY
Pre-Monsoon	Mean	77.6167	10.875	3.35	0.1583
	SD	5.9008	4.609	2.5841	0.5627
	Maximum	90	24	15	4
	Minimum	55	1	0	0
Monsoon	Mean	46.2083	49.5667	23.8417	2.3833
	SD	9.0092	9.3137	5.6701	2.4839
	Maximum	73	72	37	14
	Minimum	22	24	11	0
Post-Monsoon	Mean	49.8333	7.2417	3.425	0.5
	SD	5.3764	3.9094	2.3933	0.7853
	Maximum	60	19	10	3
	Minimum	34	0	0	0
Winter	Mean	86.725	2.7583	0.7333	0.0333
	SD	2.5947	2.1016	0.9463	0.1795
	Maximum	91	8	4	1
	Minimum	79	0	0	0

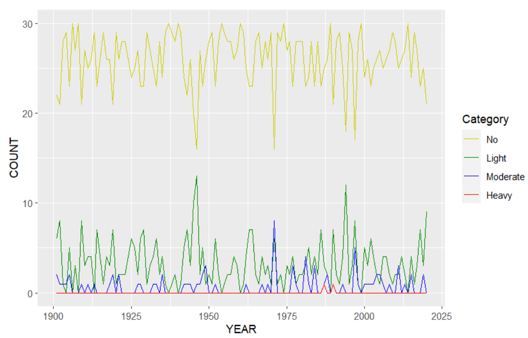


(a) January

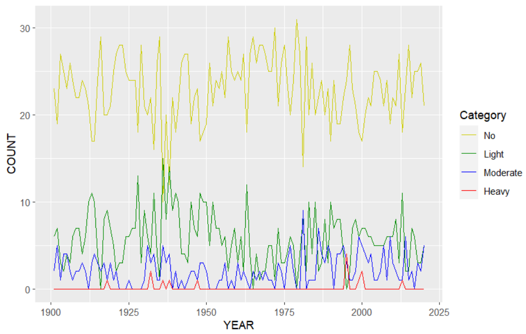


(b) February

(c) March



(d) April



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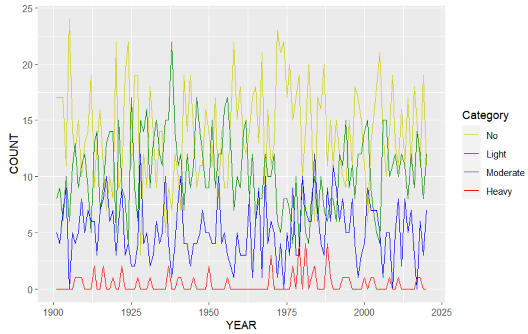
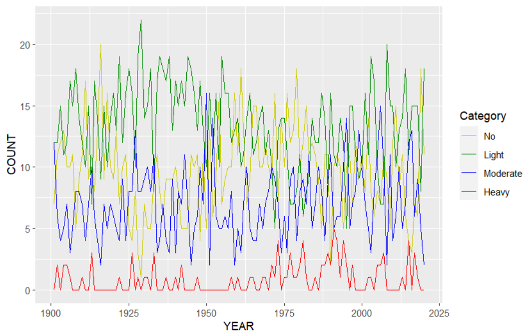
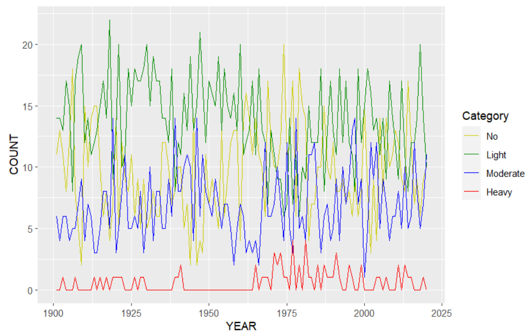


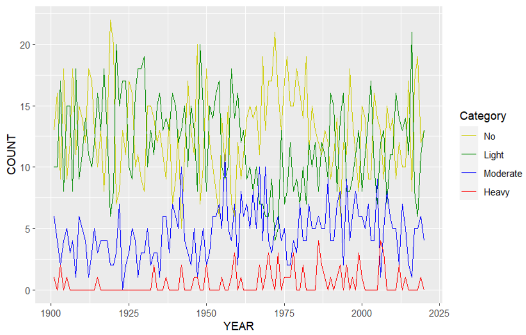
(f) June



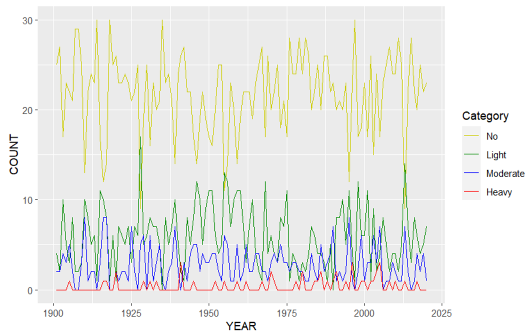
(g) July



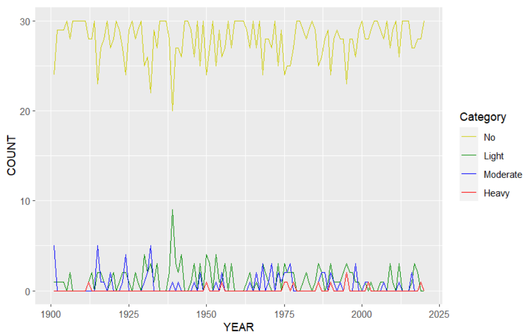
(h) August



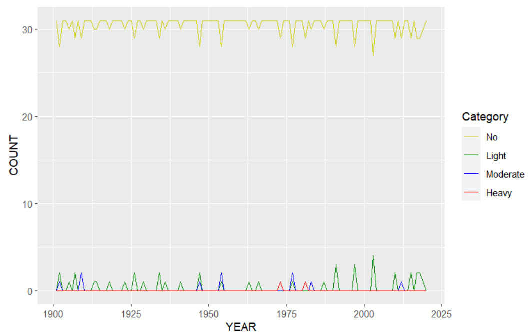
(i) September



(j) October

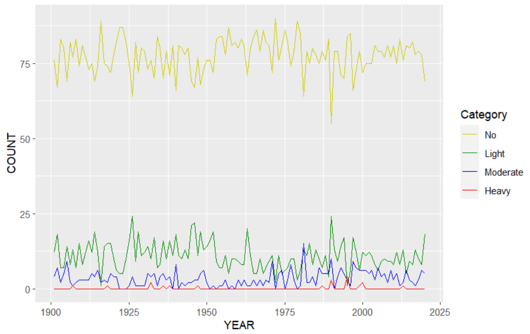


(k) November

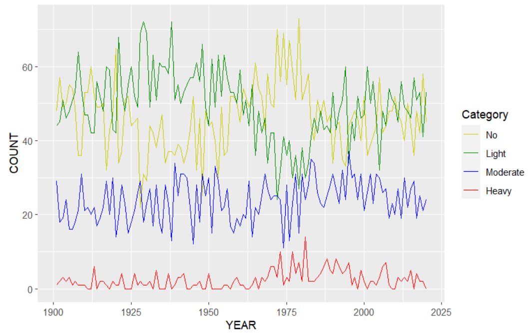


(l) December

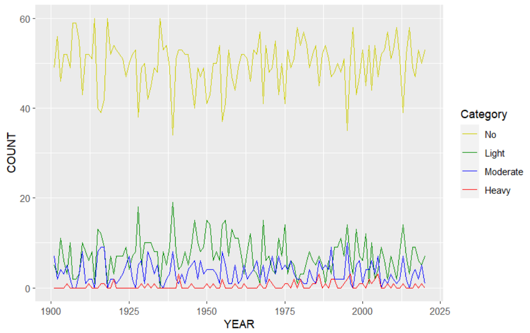
Figure 53: Monthwise Plot of Different Intensities of Rainfall in South 24 Parganas



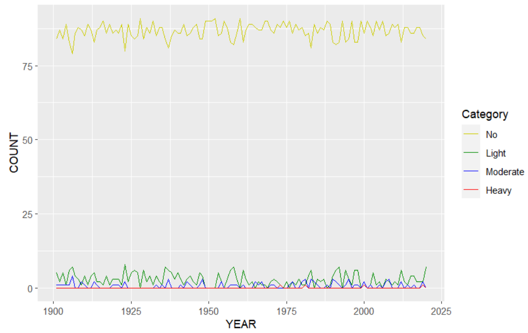
(a) Pre-Monsoon



(b) Monsoon



(c) Post-Monsoon



(d) Winter

Figure 54: Seasonwise Plot of Different Intensities of Rainfall in South 24 Parganas

5 Results

The fitted regression lines for all districts are shown in 55. For Darjeeling, the fitted regression line of Monsoon variance, MV_i on i is given by (1).

$$MV_i = 3148.8714 - 1.4130i \tag{1}$$

Here the test statistic and p-value for testing $H_0 : \beta = 0$ vs $H_1 : \beta < 0$ are t $= -3.06$ and 0.0014 respectively. To test the null hypothesis of no trend against the alternative of a downward trend, the Mann-Kendall test gives S $= -1810$ and p-value $= 0.00002$. The Theil-Sen slope estimate is -1.4090.

For Coochbehar, the fitted regression line of Monsoon variance, MV_i on i is given by (2).

$$MV_i = -1775.1598 + 1.3689i \tag{2}$$

Here the test statistic and p-value for testing $H_0 : \beta = 0$ vs $H_1 : \beta > 0$ are t $= 1.05$ and 0.1486 respectively. To test the null hypothesis of no trend against the alternative of an upward trend, the Mann-Kendall test gives S $= 56$ and p-value $= 0.4504$. The Theil-Sen slope estimate is 0.1107.

For Malda, the fitted regression line of Monsoon variance, MV_i on i is given by (3).

$$MV_i = -1242.0260 + 0.7936i \tag{3}$$

Here the test statistic and p-value for testing $H_0 : \beta = 0$ vs $H_1 : \beta > 0$ are t $= 0.937$ and 0.1754 respectively. To test the null hypothesis of no trend against the alternative of an upward trend, the Mann-Kendall test gives S=2 and p-value=0.4991. The Theil-Sen slope estimate is 0.0018.

For Purulia, the fitted regression line of Monsoon variance, MV_i on i is given by (4).

$$MV_i = -1435.1382 + 0.8289i \tag{4}$$

Here the test statistic and p-value for testing $H_0 : \beta = 0$ vs $H_1 : \beta > 0$ are t = 2.75 and 0.0034 respectively. To test the null hypothesis of no trend against the alternative of an upward trend, the Mann-Kendall test gives S=1012 and p-value=0.0109. The Theil-Sen slope estimate is 0.5006.

For Nadia, the fitted regression line of Monsoon variance, MV_i on i is given by (5).

$$MV_i = 13.0749 + 0.0872i \tag{5}$$

Here the test statistic and p-value for testing $H_0 : \beta = 0$ vs $H_1 : \beta > 0$ are t = 0.232 and 0.4087 respectively. To test the null hypothesis of no trend against the alternative of an upward trend, the Mann-Kendall test gives S=−88 and p-value=0.4218. The Theil-Sen slope estimate is −0.0411.

For South 24 Parganas, the fitted regression line of Monsoon variance, MV_i on i is given by (6).

$$MV_i = -3773.7250 + 2.0805i \tag{6}$$

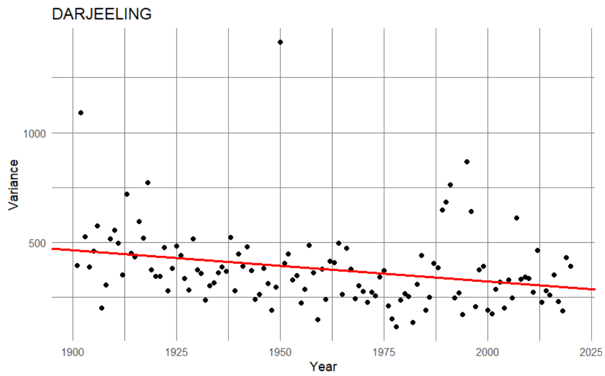
Here the test statistic and p-value for testing $H_0 : \beta = 0$ vs $H_1 : \beta > 0$ are t = 2.92 and 0.0021 respectively. To test the null hypothesis of no trend against the alternative of an upward trend, the Mann-Kendall test gives S=1594 and p-value=0.0001. The Theil-Sen slope estimate is 1.2252.

ARIMA model is fitted to 120 years (1901-2020) of Monsoon rainfall for each district. Then Monsoon rainfall for next 10 years (2021-2030) is forecasted for each district. The forecasted Monsoon rainfall value are shown in Table 31. The forecast is plotted in the Figure 56. Also 80% and 95% confidence intervals are also shown in Figure 56.

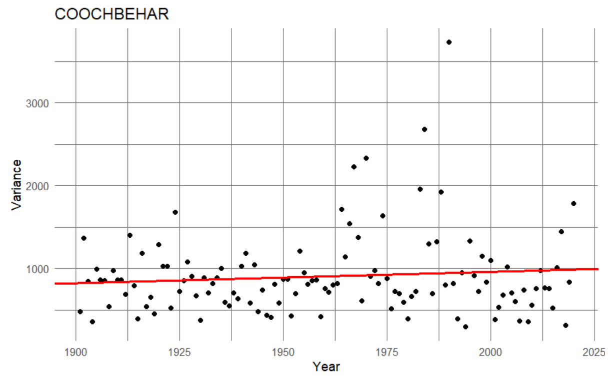
Table 31: Forecast of Monsoon Rainfall from 2021 to 2030 Using ARIMA

District	2021	2022	2023	2024	2025
Darjeeling	2580.69	2581.97	2583.25	2584.52	2585.80
Coochbehar	2601.90	2599.51	2597.80	2596.63	2595.91
Malda	1106.88	1106.18	1105.48	1104.78	1104.09
Manbhum Purulia	1110.32	1110.87	1111.42	1111.97	1112.52
Nadia	985.92	986.41	986.90	987.39	987.87
South 24 Parganas	1310.55	1285.10	1296.32	1299.25	1303.70

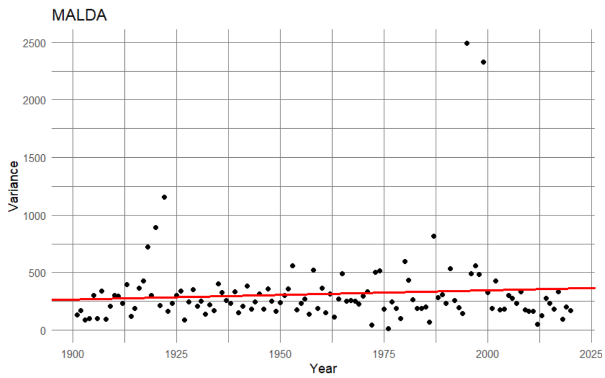
District	2026	2027	2028	2029	2030
Darjeeling	2587.08	2588.36	2589.63	2590.91	2592.19
Coochbehar	2595.56	2595.50	2595.69	2596.08	2596.63
Malda	1103.39	1102.69	1101.99	1101.29	1100.59
Manbhum Purulia	1113.07	1113.62	1114.17	1114.72	1115.27
Nadia	988.36	988.85	989.34	989.82	990.31
South 24 Parganas	1307.54	1311.26	1314.77	1318.10	1321.25



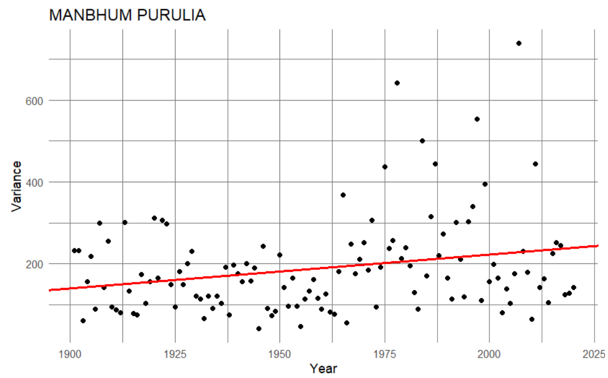
(a) Darjeeling



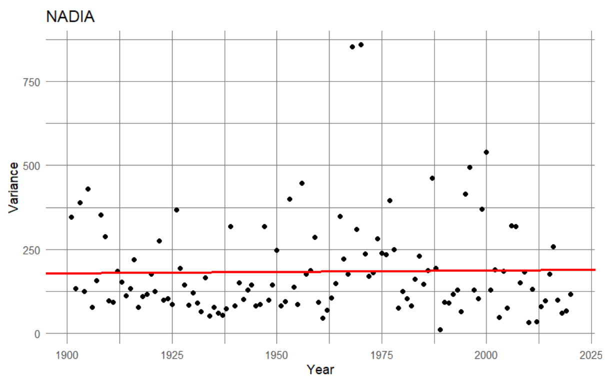
(b) Coochbehar



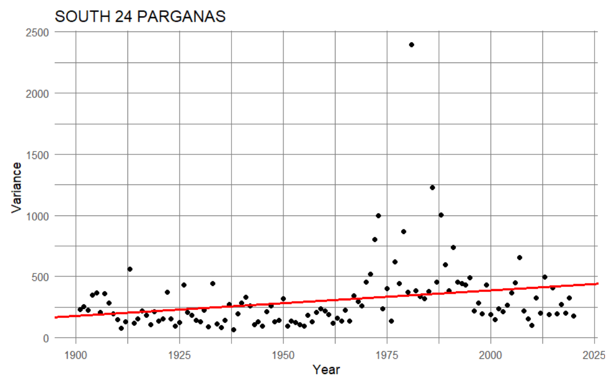
(c) Maldah



(d) Manbhum Purulia

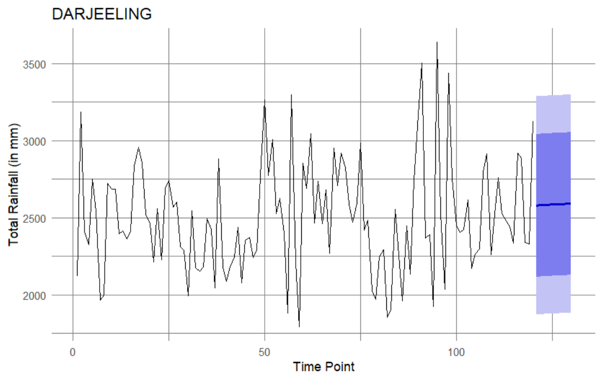


(e) Nadia

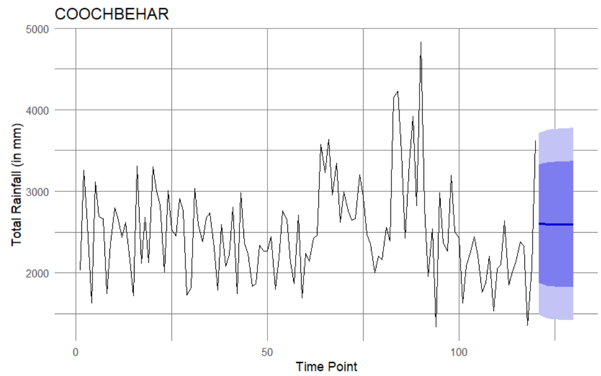


(f) South 24 Parganas

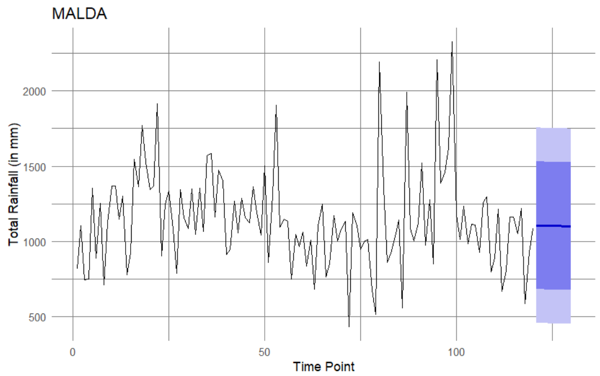
Figure 55: Linear Regression of Monsoon Variance over Years for Different Districts



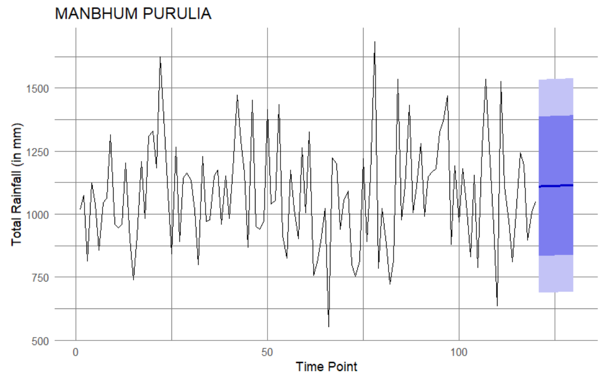
(a) Darjeeling



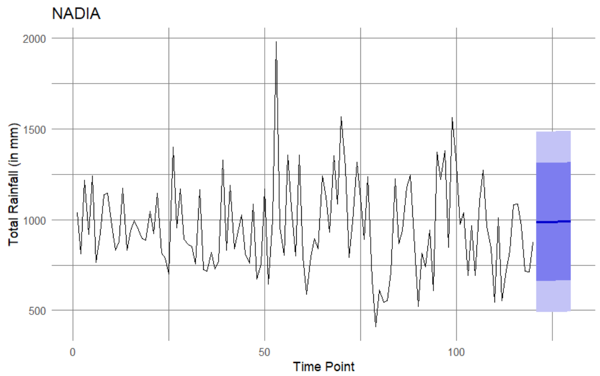
(b) Coochbehar



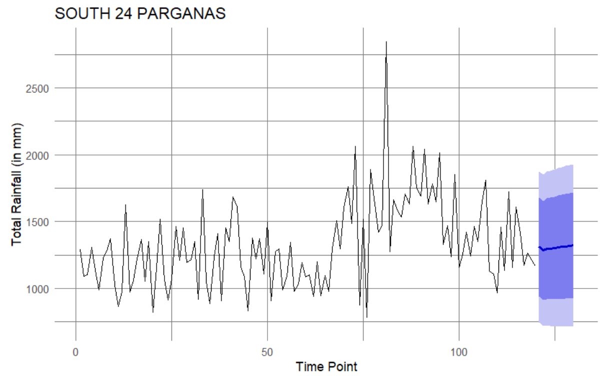
(c) Maldah



(d) Manbhum Purulia



(e) Nadia



(f) South 24 Parganas

Figure 56: Forecast of Monsoon rainfall for the years 2021-2030 Using ARIMA for Different Districts

6 Discussion

The Monsoon mean rainfall statistics from Table 32 reveals significant regional differences in rainfall within West Bengal. Coochbehar and Darjeeling receive highest and second highest mean Monsoon rainfall of 2503.6081 mm and 2503.92 mm, respectively, which are substantially higher than the overall state mean of 1385.4474 mm. This suggests that these regions receive significantly more precipitation during the Monsoon season, positioning them as outliers within the state's overall precipitation profile. Such high rainfall levels in Darjeeling and Coochbehar can have substantial implications for water resource management, agriculture, and flood risk in these areas. It can also be seen that Darjeeling has lower SD (360.5978 mm), which means Darjeeling receives high rainfall consistently than Coochbehar, which has an SD of 594.4453 mm. On the other hand, Nadia receives the lowest mean Monsoon rainfall of 956.942 mm, followed by Purulia at 1077.317 mm. These figures highlight regions that receive relatively less Monsoon rainfall, potentially facing different challenges such as water scarcity or drought conditions, which can affect agricultural productivity and water availability. Also West Bengal receives higher rainfall than overall India in Monsoon on an average.

Table 32: Statistics of Monsoon Rainfall over Various Regions

Region	MEAN	SD
Darjeeling	2503.6081	360.5978
Coochbehar	2503.92	594.4453
Malda	1149.1356	329.0803
Manbhum Purulia	1077.317	214.7234
Nadia	956.942	251.4215
South 24 Parganas	1327.8011	323.5395
WB (Our Data)	1385.4474	160.7707
WB (IMD) [10]	1418.7	197.1993
India [2]	880	90

Comparing these figures with the state average SD of 160.7707 mm reveals that most regions in West Bengal experience relatively stable Monsoon rainfall. This relative stability is even more pronounced when compared to the national data for India, where the Monsoon mean rainfall is 880 mm with an SD of 90 mm. This suggests that, on a national scale, Monsoon rainfall is generally less variable and more stable, highlighting West Bengal's distinct climatic characteristics with higher and more variable rainfall patterns.

Table 33 shows various statistics for measuring trends of Monsoon Variance. MK Test gives a negative value of TSSE (-1.409) with a p-value of 0.00002 for Darjeeling. So it can be said from MK Test that Darjeeling shows a significantly decreasing trend in Monsoon variance over 120 years. Regression test also gives a negative value of slope coefficient (-1.413) with a p-value of 0.0014, which also supports the decline obtained from MK Test. This agreement highlights a consistent and statistically significant decreasing trend in Monsoon variance over 120 years in Darjeeling.

For Coochbehar, MK Test gives a positive value of TSSE (0.1109) with a p-value of 0.4504. So it can be said from MK Test that Coochbehar shows a non-significant increasing trend in Monsoon variance over 120 years. But Regression test gives a positive value of slope coefficient (1.369) with a small p-value of 0.149, which is more or less contradictory with MK Test. So though the Monsoon variance has a increasing trend in Coochbehar, it's significance cannot be concluded properly.

For Malda, MK Test gives a positive value of TSSE (0.0018) with a high p-value of 0.4991. So it can be said from MK Test that Malda shows a non-significant increasing trend in Monsoon variance over 120 years. But Regression test gives a positive value of slope coefficient (0.7936) with a small p-value of 0.175, which is more or less contradictory with MK Test. So though the Monsoon variance has a increasing trend in Malda, it's significance cannot be concluded properly.

MK Test gives a positive value of TSSE (0.5006) with a small p-value of 0.0109 for Purulia. So it can be said from MK Test that Purulia shows a significantly increasing trend in Monsoon variance over 120 years. Regression test also gives a positive value of slope coefficient (0.8289) with a small p-value of 0.0034, which also supports the increment obtained from MK Test. This agreement highlights a consistent and statistically significant increasing trend in Monsoon variance over 120 years in Purulia.

For Nadia, MK Test gives a negative value of TSSE (-0.0411) with a high p-value of 0.4218. So it can be said from MK Test that Nadia shows a non-significant decreasing trend in Monsoon variance over 120 years. But Regression test gives a positive value of slope coefficient (0.0872) with a high p-value of 0.409, which is opposite of with MK Test. So for Nadia, Monsoon variance is stable over 120 years.

MK Test gives a positive value of TSSE (1.2252) with a small p-value of 0.0002 for South 24 Parganas. So it can be said from MK Test that South 24 Parganas shows a significantly increasing trend in Monsoon variance over 120 years. Regression test also gives a positive value of slope coefficient (2.0805) with a small p-value of 0.0021 which also supports the increment obtained from MK Test. This agreement highlights a consistent and statistically significant increasing trend in Monsoon variance over 120 years in South 24 Parganas.

MK Test gives a positive value of TSSE (0.3877) with a p-value of 0.0629 for West Bengal. Regression test also gives a positive value of slope coefficient (0.5151) with a p-value of 0.0204. From these figures, though an increment is observed in Monsoon variance over 120 years, it cannot be concluded properly whether it is significant or not.

For Darjeeling, Purulia, South 24 Parganas and overall West Bengal, TSSE and slope coefficient from Regression agrees well. For Coochbehar and Malda, TSSE gives low values than Regression slope coefficient. This may happen because TSSE is not affected by extreme values, where Regression slope coefficient becomes afftected. For Nadia, they even disagree, as TSSE gives negetive value (-0.0411) and Regression gives positive slope (0.0872).

Table 33: Statistics of Trends of Variance over Various Regions

Region	Beta Coefficient (Regression)	P-Value (Beta Coefficient)	MK Test Statistics	P-Value (MK Test)	Sen's Slope Estimator
Darjeeling	-1.413	0.0014	-1810	0.00002	-1.409
Coochbehar	1.369	0.149	56	0.4504	0.1109
Malda	0.7936	0.175	2	0.4991	0.0018
Manbhum Purulia	0.8289	0.0034	1012	0.0109	0.5006
Nadia	0.0872	0.409	-88	0.4218	-0.0411
South 24 Parganas	2.0805	0.0021	1594	0.0002	1.2252
WB (Our Data)	0.5151	0.0204	676	0.0629	0.3877

Future Scope: The research on this project is ongoing, with several key areas identified for further exploration. One of the primary objectives is to identify potential change points in the rainfall patterns of West Bengal. Detecting these change points will provide insights into shifts in Monsoon and their impacts on the region's rainfall. In addition to identifying change points, we aim to propose an alternative measure of dispersion for rainfall data, beyond the traditional use of variance. Developing new dispersion metrics could offer a more nuanced understanding of rainfall variability and better capture the complexities inherent in rainfall patterns. Moreover, rainfall in any region is influenced by a multitude of climatic factors, including temperature, humidity, wind direction, and others. Future studies will focus on incorporating these variables into the analysis to provide a more comprehensive understanding of rainfall characteristics. By integrating these climatic factors, we can develop more robust models that account for the interplay between different atmospheric conditions and rainfall. These future directions will enhance the overall understanding of rainfall patterns in West Bengal and contribute to more accurate predictions and better-informed climate adaptation strategies for the region.

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