**Original Research Article**

# A statistical perspective on rainfall pattern and its impact on agriculture, economy, and tourism in India


### Abstract

The current study examines rainfall trends in India, encompassing its effect on various economic aspects and forecasting for 2023-2030. The Mann-Kendall test and Sen's slope estimator are utilized to analyze annual and seasonal rainfall patterns. Results reveal a pronounced winter decline (2001-2022) alongside significant pre-monsoon, monsoon, and post-monsoon increases. Annual rainfall consistently decreases, contrasting with rising pre-monsoon, monsoon, and post-monsoon trends. Annual rainfall exhibits the steepest decline (-1.0891 mm/year), while the monsoon season displays the highest increase (3.2538 mm/year). Further, the present study explores relationships between rainfall and economic growth, tourism, and agriculture. A statistically insignificant yet positive correlation is found between annual rainfall and per-capita GDP, indicating other economic drivers. Tourism shows a weak, statistically insignificant link with annual rainfall. In contrast, a robust statistically significant correlation emerges between annual rainfall and food-grain production, highlighting its role in agriculture. Finally, the present research forecasts annual rainfall (2023-2030) using the ARIMA(1,0,0) model, predicting a continued decline. This has profound implications for water resources, agriculture, and the economy, necessitating proactive measures such as water conservation, drought-resistant farming, and alternative energy investments.


*Keywords:* Rainfall; Non-parametric test; Trend; Correlation; ARIMA;

# 1 Introduction

Rainfall is the precipitation of condensed water droplets from clouds under the effects of gravity, falling to the earth at varied precipitation rates. Rainfall forms an unassailable phenomenon in the water cycle and is indispensable in connecting climate and weather. The primary mechanism through which rain precipitates on the Earth's surface is through the transformation of atmospheric water vapor into liquid or solid water droplets. Rainfall occurs by several important mechanisms, including evaporation, atmospheric moisture, condensation nuclei, cloud formation, precipitation, rainfall distribution, and ground impact Bogardi and Fekete [2021]. India experiences two types of precipitation mainly southwest monsoon (June to September) and northeast monsoon (October to December). In India, nearly 75 % of rainfall is obtained from the southwest monsoon and 25 % from the northeast monsoon. Rainfall is measured using rain gauges Leong [1995], which measure the amount of water in a particular region and a particular period, and the rainfall is measured in millimeters per hour (mm).

Rainfall plays a significant role in influencing agriculture, tourism, and economic development in various ways. In agriculture, insufficient or inconsistent rainfall can affect crops, resulting in lower yields and losses due to drought ( Lemmen and Warren [2004]). On the other hand, floods and excessive rain can both harm crops and soil and interfere with farming. Rainfall has an impact on soil quality, pest frequency, crop selection, and planting periods Pathak et al. [2012]. Besides agriculture, tourism can also be greatly affected by rainfall, as some locations depend on rain to draw visitors for activities like water sports. Moreover, excessive or badly timed rain can interrupt travel arrangements and outdoor activities, and result in a decline in the number of visitors, subsequently impacting the financial stability of the tourism sector ( preetu venugopalan nair [2013]). Another important effect of rainfall is on the economic development of the region through secondary effects, in particular agriculture and food security, health and education, insurance costs and planning, etc., To understand the effect of rainfall, numerous studies investigated the rainfall and its statistical analysis, and the various types of studies include trend analysis, effects of rainfall in different sectors and the future forecast.

Several studies Sanikhani et al. [2018], Gajbhiye et al. [2016], Krishnakumar et al. [2009], Sharma et al. [2021], Shree and Kumar [2018] investigated the analysis of rainfall trends. Sanikhani et al. [2018] investigated the rainfall trend in central India from 1901-2010, using statistical analysis, and found that there was no significant trend in the months of January and October. The study was performed on 20 stations in Chattisgarh and Madhya Pradesh. In Chattisgarh, only four of the total five stations were significant, while two out of 15 stations in Madhyapradesh exhibited significant annual trends. The annual rainfall was found to portray a decreasing trend in 16 stations, while the season shows an increasing trend (i.e., summer (16 stations), monsoon (11 stations), winter (12 stations), and post-monsoon (11 stations)). Gajbhiye et al. [2016] investigated the rainfall trend for the Sindh River basin in India from 1901 to 2002 and observed the trend to be increasing in both annual and seasonal rainfall. However, in the years between 1942 and 2002, there was a decreasing rainfall trend. Krishnakumar et al. [2009] studied rainfall trends over Kerala in the twentieth century using statistical analysis (Linear trend, Menn Kendall test ( To [2016])). The seasonal premonsoon, post-monsoon, and winter rainfall trend was found to be insignificantly increasing, while the rainfall was found to be decreasing during the southwest monsoon. According to this study, the tropical easterly jet stream was found to play a vital role phenomena in the southwest monsoon. Sharma et al. [2021] examined the temperature and rainfall trend in Rajasthan from the period 1971 to 2019. The study noted a decreasing trend in Bikaner, Jaipur, and Jodhpur districts, whereas Kota and Udaipur were found to have an insignificant increasing trend. This study also depicted a variation in temperature and rainfall in different months, despite the minimum and maximum temperatures in all stations exhibiting a positive trend. The analysis of rainfall trends (annual and seasonal) for Ranchi districts was performed by Shree and Kumar [2018] from 1901 to 2014 and using the statistical analysis, the pre and post-monsoon were observed to show an insignificant positive trend and slope magnitude, whereas, winter and monsoon showed a negative trend and slope magnitude. The study found that the low monsoon season was caused due to a cyclonic storm and jet stream intensity drop over the Bay of Bengal.

Complementing the aforementioned investigations Sanikhani et al. [2018], Gajbhiye et al. [2016], Krishnakumar et al. [2009], Sharma et al. [2021], Shree and Kumar [2018] in rainfall trends, multiple studies Ndamani and Watanabe [2015], Abbas and Mayo [2021], Erkan and DİKEN [2020], Taylor and Ortiz [2009] looked into the effect of rainfall on agriculture, economic growth and tourism. Ndamani and Watanabe [2015] investigated rainfall fluctuation and its effects on crop production in Ghana's Laura districts. The findings of this study indicate a moderate seasonal and erratic annual rainfall concentration and show a negative correlation between rainfall in June and annual crop production. The study found that selecting the right methods and putting them into practice was crucial for increasing the yield of sorghum, millet, and groundnuts. The impact of temperature and rainfall on rice production in Punjab was studied by Abbas and Mayo [2021] from 1981 to 2017. During 1981 and 1993, rice production showed a declining trend, and from 1993 to 2009, it portrayed a rising trend. According to this study, the rice plant was found to be negatively impacted by rainfall during the heading and blooming stages. The reproductive phase was found to have a significant negative influence on gross domestic output per person. Erkan and DİKEN [2020] investigated the effects of rainfall on economic growth in Turkey and observed that the economy, particularly in terms of employment, is dominated by the agricultural sector. According to this study, rainfall and the agriculture sector are positively correlated. The result of the study suggests that the amount of rainfall in Turkey has more significant effects on economic growth than previously anticipated. Taylor and Ortiz [2009] looked into the effects of climate change on domestic tourism in the UK and from this study, it was observed to exhibit significant impacts on domestic tourism. Domestic travel was predicted to rise as a result of climate change since the UK's summers are expected to be hotter than they are today. The study concludes that the local tourism industry may be impacted, as well as an increase in the relative appeal of international travel destinations.

In addition to looking into the effects of rainfall and its statistical inferences, it is also vital to forecast the rainfall to understand the future effects on agriculture, economic growth, and tourism. To that effect, studies Bari et al. [2015], Graham and Mishra [2017], Basha et al. [2020], Sopipan [2014], Bett et al. [2021] investigated the future forecast using different statistical methods. Bari et al. [2015] scrutinized the monthly rainfall using the ARIMA Harvey [1990] model in Sychlet City from 1980 through 2010. The prediction was done for the period from 2007 to 2010 and the ARIMA model was built using the Box and Jenkins Box [2013] method to perform the forecast. The study was able to forecast with a confidence limit of 95% and the ARIMA (0,0,0)(1,1,1) and ARIMA (0,0,1)(1,1,1) were found to have significant results. The rainfall forecast in the Allahabad region was investigated by Graham and Mishra [2017] using the Box-Jenkins method, to develop monthly rainfall from 1985 through 2015. Nevertheless, the accuracy of predictions made for rainfall by the seasonal ARIMA model was less, as the data contained many missing values. The best model identified in this study is ARIMA (0,0,0)(0,1,0) with a 95% confidence level. Basha et al. [2020] conducted a study on rainfall forecasting using multi-layer perceptron and auto-encoder neural networks, where the results are analyzed in terms of mean (MSE) and root mean square errors (RMSE) Hodson [2022]. The study utilized several methods like ARIMA, artificial neural networks (ANN), logistic regression, support vector machine, and self-organizing maps. Compared to all other methods, ANNs were found to provide better predictions. Sopipan [2014] utilized Holt's winter exponential smoothing Kalekar et al. [2004] and Box-Jenkins method to forecast rainfall in Thailand. The best model was identified to be ARIMA (1,0,1)(1,0,1) and the study proposed strategies for agriculture, drainage systems, and other water resource applications. Bett et al. [2021] investigated the seasonal forecast for the Yangtze River basin using linear regression performing a three-month forecast (May-June-July and June-July-August) using dynamic prediction. The forecast consistently and strongly predicted an above-average rainfall for the Yangtze region and an irregularly heavy precipitation during the summer.

Despite the existence of numerous studies in the literature investigating various aspects of rainfall, these studies did not look into the analysis of seasonal trends over India (2000-2022) and the impacts of rainfall on total food grains in India (2011-2022), number of visitors who visited India during the years (2011-2022), and the economic growth in

India (2011-2022). Moreover, no studies exist to the best extent of our knowledge that study agricultural development, economic growth, and tourism in conjunction with rainfall in India. Thus, the present work aims to: 1) Study the rainfall pattern in India, followed by 2) analyze and estimate the rainfall pattern that affects agriculture, tourism, and economic development, and 3) forecast the rainfall in India from 2023 through 2027. This article is organized as follows: The information about the data used and the various statistical methods used in the present work are discussed in Sec. 2, followed by a discussion on the observations made in the present work in Sec. 3, with the conclusion summarized in Sec. 4.

## 2 Statistical methodology

In the current study, the annual rainfall data from 1971 to 2022 was obtained from meteorological data on Indiastat.com IndiaStat [2018]. The data consists of variables such as pre-monsoon (March-May), post-monsoon (October-December), winter (January-February), and the monsoon season (June- September). In addition to the rainfall data, the present study also considers the statewide per-capita net state domestic product at factor cost in India from 2011 to 2023. To account for the effects of rainfall on agriculture and tourism, the agricultural (total food grain production) data from 2011 to 2022 and the tourism data - tourists who visited 32 states in India from 2011 through 2022 have been utilized. All the aforementioned data has been obtained from Indiastat.com IndiaStat [2018]. The data used in the present study are sorted into annual data using the Microsoft Excel spreadsheet.

The statistical tools used for the analysis are IBM SPSS 26, R Studio, and Microsoft Excel. The present study employs the Mann-Kendall (MK) trend test (Kendall [1975], Mann [1945]), a popular non-parametric approach to identify significant trends in time series. The MK test statistic (S) is calculated using:

$$S = \sum_{i=1}^{n-1} \sum_{k=i+1}^{n} \text{sign}(y_i - y_k) \tag{1}$$

where,

$$sign(y_i - y_k) = \begin{cases} +1, & \text{if} \quad y_i - y_k > 1; \\ 0, & \text{if} \quad y_i - y_k = 0 \\ 1, & \text{if} \quad y_i - y_k < 1. \end{cases} \quad (2)$$

In Eq.1 and 2, $n$ represents the sample size and $y_i$ and $y_k$ represents the $i^{th}$ and $k^{th}$ observation respectively in the time series. The Mann-Kendall statistical test relies on the positive or negative signs (+ or -) of the differences between data points rather than the specific values of the data points themselves. In addition to the Mann-Kendall trend test, the present study utilizes Sen's slope estimator (Sen [1968]) to obtain the slope or magnitude of the trend in a time series dataset. The slope $S_{ik}$ is calculated using:

$$S_{ik} = \frac{y_i - y_k}{i - k} \quad (3)$$

In Eq. 3, $S_{ik}$ represents the rate of change between the data points $y_i$ and $y_k$, and the linear trend obtained using $S_{ik}$ is used to observe increasing and decreasing nature of the data. Moreover, the present study involves descriptive statistics to show the annual rainfall distribution, and also, compare several seasons to understand the significant difference between different seasons. Further, correlation studies are undertaken to ascertain the effects of rainfall on agriculture, economic growth, and tourism. Finally, the Auto-Regressive Integrated Moving Average (ARIMA) Box et al. [2015] is used along with the non-seasonal rainfall data to forecast the annual rainfall in India for the years 2023 to 2030.

# 3 Results and discussion

The dataset provided in Fig. 1 represents annual rainfall measurements in millimeters per year spanning the years from 2000 to 2022. Examination of the data reveals a notable degree of variability in annual precipitation levels over these 23 years, with values ranging from 920.8 mm/year in 2002 to a high of 1284.1 mm/year in 2019 and 1280.6

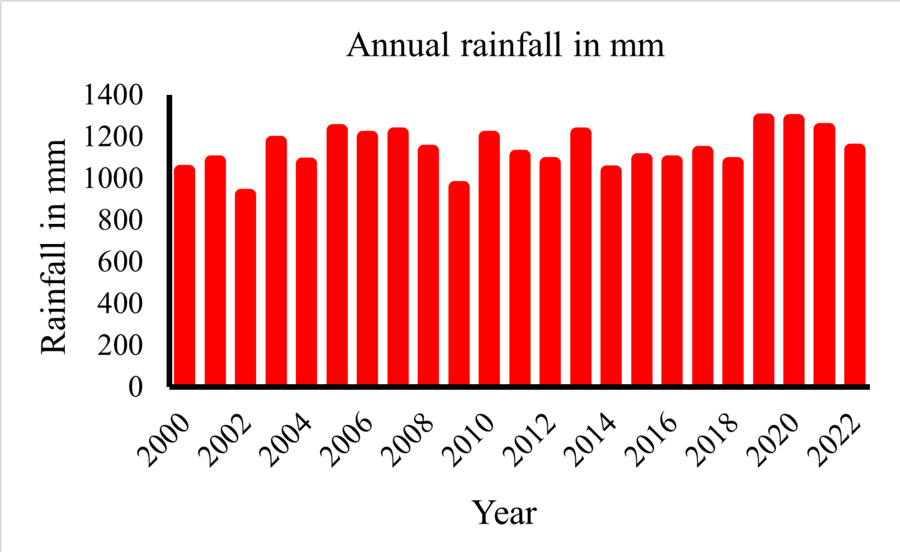



Figure 1: Annual precipitation of rainfall (mm/year) in India from the year 2000 through 2022.

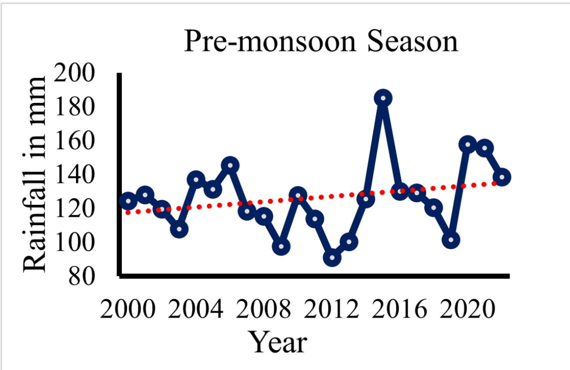
mm/year in 2020. Unlike a consistent upward or downward trend, the dataset exhibits fluctuating values with both increases and decreases in annual rainfall from one year to the next. Several years stand out as experiencing notably higher annual rainfall, including 2005 with 1232.5 mm/year, 2013 with 1216.2 mm/year, 2019 with 1284.1 mm/year, and 2020 with 1280.6 mm/year. Conversely, certain years, such as 2002 with 920.8 mm/year, 2009 with 959.3 mm/year, and 2014 with 1033.7 mm/year, recorded lower annual rainfall values, dropping below 1000 mm/year. The most recent data point for the year 2022 reports an annual rainfall value of 1169.901 mm/year. These findings highlight the dynamic and non-linear nature of annual precipitation trends, suggesting the influence of various environmental factors that warrant further investigation for a comprehensive understanding of local climate dynamics.

## 3.1 Trend analysis for annual and seasonal rainfall

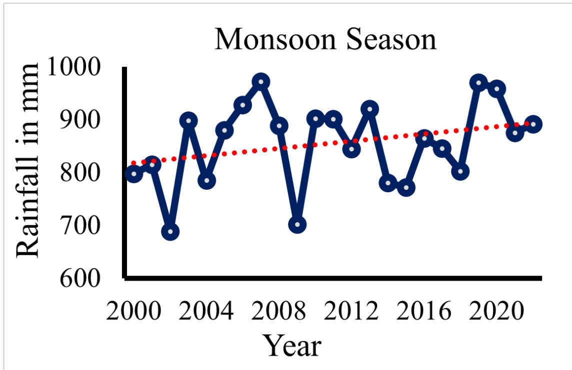
The study encompasses an examination of seasonal rainfall patterns, delineated into four discrete segments, namely, winter, pre-monsoon, monsoon, and post-monsoon, as dictated by the analysis of rainfall data spanning the years 2000 to 2022. Employing a combination of Sen's slope estimator and the Mann-Kendall test, the investigation scrutinized the temporal evolution of rainfall dynamics during the extended interval from

| Annual/Seasonal rainfall | Z-Statistics | Sens slope (mm/year) | P-Value | Trend |
|---|---|---|---|---|
| Winter | -0.1411 | -0.0734 | 0.8878 | Decreasing |
| Pre-monsoon | 0.7331 | 0.65 | 0.4635 | Increasing |
| Monsoon | 0.7895 | 3.2538 | 0.4298 | Increasing |
| Post- monsoon | 0.6767 | 1.3909 | 0.4986 | Increasing |
| Annual | -0.8778 | -1.0891 | 0.2269 | Decreasing |

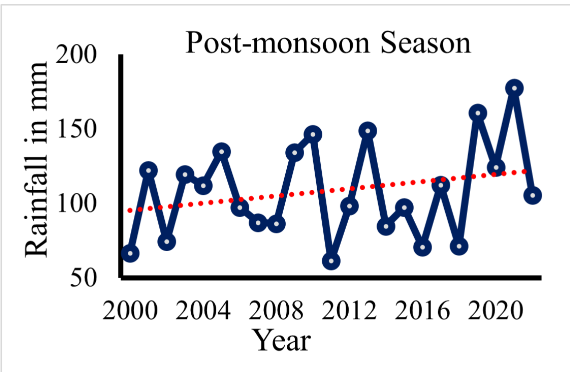
Table 1: Trend analysis of annual and seasonal rainfall based on Mann-Kendall test and Sen's Slope estimator.



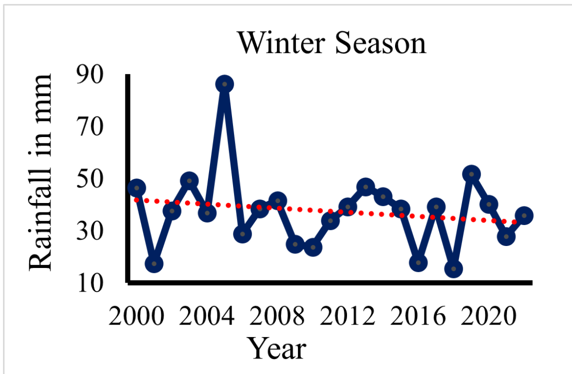

(a) Pre-monsoon




(b) Monsoon




(c) Post-monsoon




(d) Winter

Figure 2: Linear trends for the rainfall in India for the a.) pre-monsoon, b.) monsoon, c.) post-monsoon, and d.) winter seasons. The solid blue line represents the rainfall data while the dashed red line depicts the linear trend.

2000 to 2022. The ensuing presentation of findings is encapsulated within Table 1, which provides a detailed exposition of the statistical outcomes grounded in Z statistics.

The Mann-Kendall test was utilized to assess the existence and statistical significance of trends within distinct seasonal periods. The test relies on Z-statistics, which serve as a pivotal indicator of the presence of trends. During the winter season, the computed Z-statistic of -0.1411 underscored a trend of nominal consequence, suggesting minimal decreasing variation in precipitation patterns. Conversely, the pre-monsoon, monsoon, and post-monsoon seasons exhibited Z-statistics of 0.7331, 0.7895, and 0.6767, respectively. These values signified the potential emergence of discernible increasing trends within these specific seasonal segments. However, the Z-statistic calculated for the annual period, denoted as -0.8778, offered a distinct observation. It indicated the presence of a discernible decreasing trend over the entire year, thereby warranting heightened attention and further examination of the factors contributing to this overarching trend in annual rainfall patterns and its contrasting nature with seasonal rainfall patterns. Furthermore, Sen's slope analysis was utilized to estimate the rate of change in rainfall over time. While the annual rainfall and winter precipitation are experiencing a decrease in rainfall at rates of -1.0891 mm/year and -0.0734 mm/year, respectively, the pre-monsoon, monsoon, and post-monsoon seasons are simultaneously on an upward trajectory in terms of precipitation (see Table 1). The pre-monsoon season is seeing an increase of 0.65 mm/year, the monsoon season is showing a substantial rise of 3.2538 mm/year, and the post-monsoon season is also witnessing growth with a rate of 1.3909 mm/year. This contrast reveals an intriguing pattern where the annual and winter seasons are becoming drier, while the transitional and monsoon seasons are becoming wetter over time, indicating a shift in the distribution of rainfall throughout the year. Over the past 23 years, no consistent pattern in precipitation trends was evident. Nevertheless, a declining trend has become apparent since 2019, suggesting a reduction in precipitation (see Fig. 1). The analysis of linear trends in annual and seasonal rainfall, specifically for pre-monsoon, monsoon, post-monsoon, and winter periods, is presented graphically in Figure 2.

## 3.2 Effects of rainfall

### 3.2.1 Effects on Economic growth

Understanding the relationship between environmental factors, such as annual rainfall, and economic indicators like per-capita domestic product, holds significant importance for policymakers, researchers, and stakeholders alike. Such analysis can shed light on the interplay between climate and economic outcomes, aiding in the development of

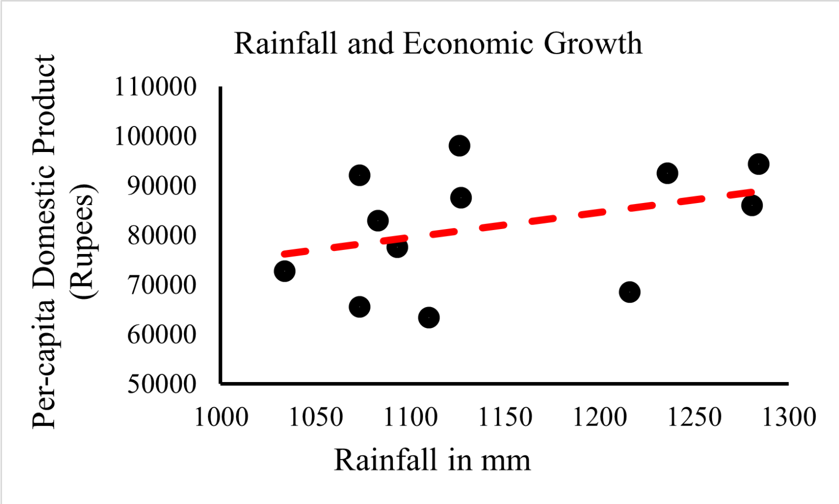



Figure 3: The relationship between annual rainfall in mm and the per-capita domestic Product at factor cost in India (Rupees). The symbols represent the data used in the present work while the dashed line represents the trend between rainfall and economic growth.

informed strategies for sustainable economic growth and resilience in the face of changing environmental conditions.

Figure 3 portrays the relationship between annual rainfall in mm/year and the per-capita domestic product at factor cost (in Rupees) in India. The analysis of the relationship between annual rainfall and per-capita domestic product, as indicated by the Pearson correlation coefficient (R-value) of 0.429 and an associated p-value of 0.164, reveals a positive but non-statistically significant correlation. The positive R-value suggests that as annual rainfall levels increase, the per-capita domestic product tends to increase, indicating a potential positive influence of precipitation on economic productivity. However, the non-statistically significant p-value of 0.164 implies that this observed correlation may be attributed to random chance rather than a robust and causal relationship. It is important to exercise caution when interpreting these findings, as various unaccounted-for factors may be influencing the relationship between rainfall and per-capita domestic product. Further research and consideration of additional variables are necessary to gain a comprehensive understanding of the multifaceted factors that impact economic performance in India.

### 3.2.2 Effects on Tourism

To understand annual rainfall and its impact on tourism, the analysis of the correlation between these variables in the context of India is of paramount significance and has been undertaken in the present work. Figure 4 represents the association between rainfall in mm/year and the number of tourists visiting India in crores. Exploring the correlation between annual rainfall and the influx of tourists to India, as elucidated by the correlation coefficient (R-value) of -0.130 and the accompanying p-value of 0.688, reveals a tenuous and statistically insignificant negative correlation. The adverse R-value implies a marginal tendency for tourist numbers to exhibit a slight reduction with increasing annual rainfall, indicating a conceivable but exceedingly weak inverse association. However, the elevated p-value of 0.688 intimates that the observed correlation is not statistically significant, failing to meet the conventional 0.05 significance threshold. This suggests that the interplay between rainfall and tourist arrivals may be governed by stochastic variations rather than a substantiated and deterministic relationship. In the year with the highest recorded rainfall (1284.1 mm/year), 2019, the remarkable upswing in domestic tourism (232 crore tourists) stands out as an outlier. This anomaly can be attributed to a confluence of factors, including the increasing disposable incomes of travelers, the burgeoning presence of millennial tourists, a surplus of leisure time, and the diversifica-

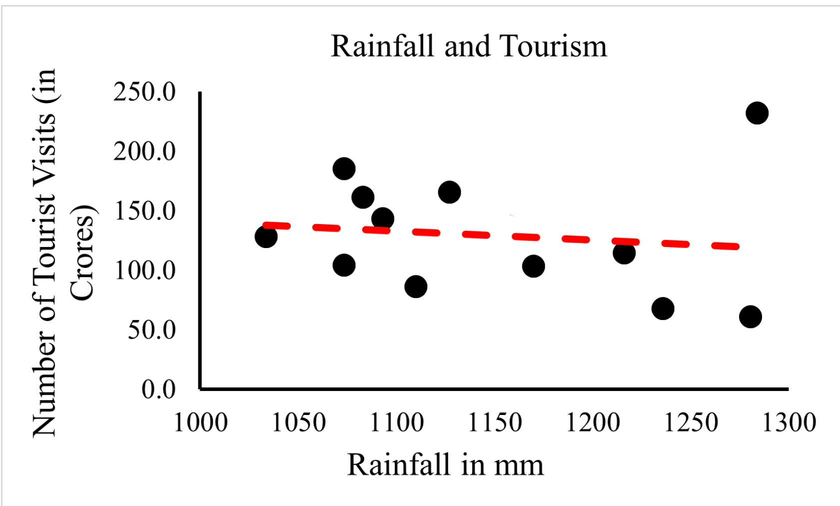



Figure 4: The relationship between annual rainfall in mm and the number of domestic tourists visiting India in crores. The symbols represent the data used in the present work while the dashed line represents the trend between rainfall and growth in tourism.

tion of tourism themes Pujar and Mishra [2021], Karanth and DeFries [2011], Nair and Ramachandran [2016]. This outlier, characterized by the highest rainfall and a substantial surge in tourist numbers, can substantially influence the outcomes of a correlation analysis by affecting the R-value and P-value. Tourism trends, therefore, can depend on a multitude of mutually exclusive variables beyond rainfall, such as rising disposable incomes, preferences, novel tourism themes, etc., These outcomes accentuate the intricacy of variables governing tourist visitation patterns in India, necessitating further extensive investigation to elucidate the nuanced determinants affecting tourist flow to the nation.

### 3.2.3 Effects on agriculture

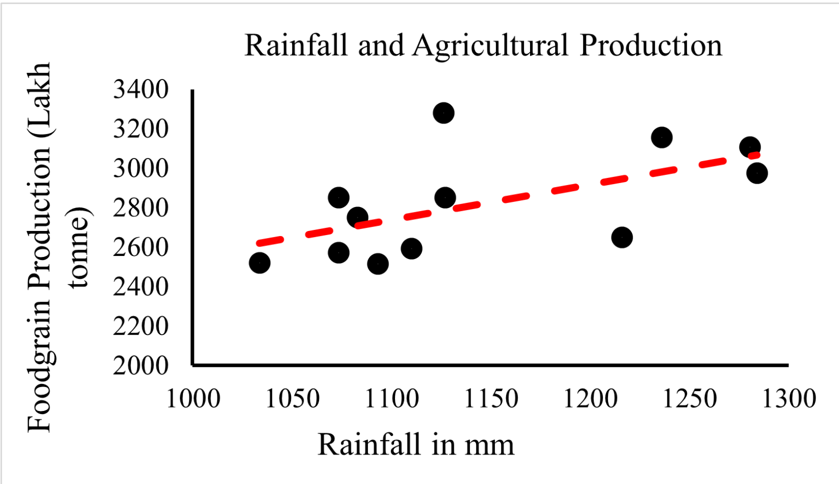


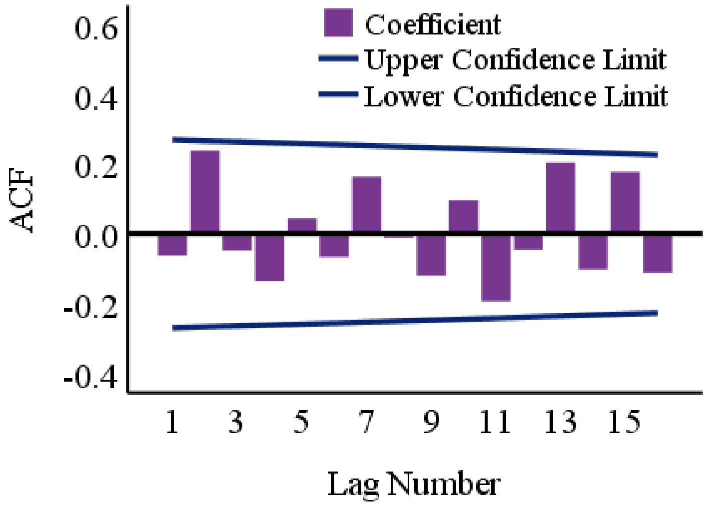

Figure 5: The relationship between rainfall in mm and the foodgrain production total in India (lakh tonne). he symbols represent the data used in the present work while the dashed line represents the trend between rainfall and agricultural production.

Figure5 depicts the relationship between rainfall in mm and the foodgrain production in India (lakh tonne). The correlation analysis between annual rainfall (in mm/year) and foodgrain production (in lakh tonnes) reveals a strong and positive relationship with an R-value of 0.666. This R-value suggests a substantial positive correlation between the two variables, indicating that as annual rainfall increases, foodgrain production tends to increase as well. Furthermore, the associated p-value is 0.018, which is statistically significant at a 0.05 significance level. This low p-value indicates that the observed correlation is unlikely to have occurred by random chance. It strengthens the case for a genuine and robust positive correlation between annual rainfall and foodgrain production. In summary, the data suggests a significant and positive correlation between annual rainfall and foodgrain production, with higher rainfall generally associated with increased foodgrain yields. This finding can be valuable for agricultural planning and resource management, as it underscores the influence of climate factors on food production.

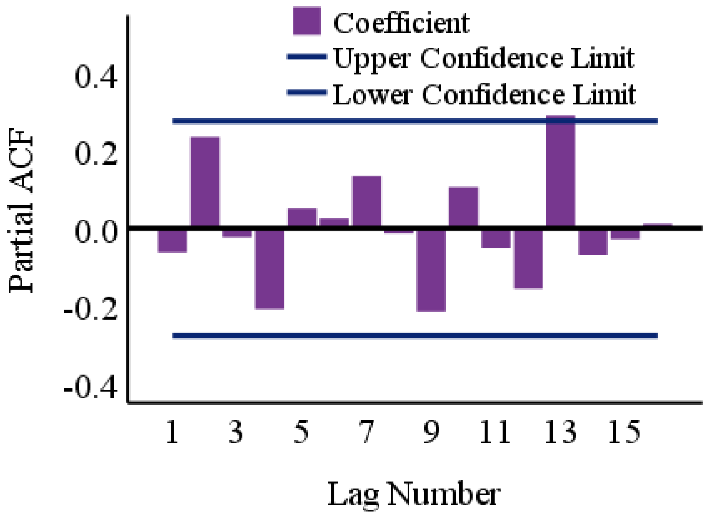
### 3.3 Prediction for precipitation

In the realm of time series analysis and forecasting, the selection of an appropriate model plays a pivotal role in capturing the underlying patterns within the data. The Auto-Regressive Integrated Moving Average (ARIMA) model framework is a widely employed method for this purpose, characterized by its parameterization as (p, d, q), representing the auto-regressive order, differencing order, and moving average order, respectively. The current study focuses on the analysis of annual rainfall data spanning from 1971 to 2022, with the primary objective of determining the most suitable ARIMA model to facilitate accurate rainfall forecasting. The initial steps in the analysis involved assessing the stationarity of the time series data. The autocorrelation function (ACF) and partial autocorrelation function (PACF) were employed to investigate the necessity of differencing (d) to stabilize the data. Results from this analysis indicated that the data remained stationary without any differencing, as the ACF and PACF coefficients adhered closely to the confidence intervals, signifying a lack of temporal trend or seasonality. The ACF and PACF obtained in the present work are shown in Fig. 6.

Subsequently, a series of candidate ARIMA models with different (p, d, q) configurations were considered as shown in Table 2. Model selection was based on the Bayesian Information Criterion (BIC), a widely accepted criterion that balances model fit and complexity. The BIC values obtained for each model served as a key metric for assessing their performance. Among the tested models, the ARIMA(1,0,0) configuration displayed the most promising performance, yielding the lowest BIC value of 9.457 (see Table 2). A lower BIC value is indicative of a more suitable trade-off between model fit and complexity, reinforcing the efficacy of the ARIMA(1,0,0) model for the forecasting task. In addition




(a) ACF




(b) PACF

Figure 6: Auto-correlation function (ACF) and partial auto-correlation function (PACF) without differencing for the annual rainfall time series data from 1971 to 2022.

to the BIC, model selection and performance assessment also encompassed the utilization of other essential metrics such as the Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and normalized BIC. These metrics were employed to fine-tune the model, ensuring its compatibility with a 95% confidence interval, which is a crucial aspect of model validation and reliability.

The ARIMA(1,0,0) model, chosen after rigorous analysis of stationarity through ACF and PACF plots, is employed to offer annual rainfall forecasts from 2023 through 2030.

| Model type | BIC |
|---|---|
| ARIMA (1,0,0) | 9.457 |
| ARIMA (1,0,1) | 9.538 |
| ARIMA (0,0,1) | 9.458 |
| ARIMA (1,0,2) | 9.571 |
| ARIMA (0,0,2) | 9.475 |
| ARIMA (2,0,0) | 9.502 |
| ARIMA (2,0,1) | 9.600 |
| ARIMA (2,0,2) | 9.634 |

Table 2: ARIMA model parameters (p, d, q) and the corresponding Bayesian information criterion (BIC) values in the present work.

Table 3 provides the forecasted annual rainfall values for the period from 2023 to 2030, along with their respective upper and lower 95% confidence intervals (UCL and LCL). Despite a predicted decrease in annual rainfall of approximately 1 mm/year, a clear trend of decreasing annual rainfall is evident throughout the forecast horizon. In 2023, the forecasted annual rainfall is 1141.12 mm, falling within the range of 938.30 mm (LCL) to 1343.94 mm (UCL). This decreasing trend continues through 2030, with successive years exhibiting a reduction in forecasted rainfall. The use of confidence intervals further acknowledges the inherent uncertainty in the forecasts, providing a quantifiable range within which actual rainfall values are expected to fall, with a 95% confidence level. This range encompasses the plausible variations in annual rainfall, enabling the decision-makers for risk assessment and contingency planning.

| Year | UCL | LCL | Forecast |
|---|---|---|---|
| 2023 | 1343.94 | 938.30 | 1141.12 |
| 2024 | 1343.56 | 936.92 | 1140.24 |
| 2025 | 1342.91 | 936.27 | 1139.59 |
| 2026 | 1342.25 | 935.60 | 1138.93 |
| 2027 | 1341.58 | 934.94 | 1138.26 |
| 2028 | 1340.92 | 934.27 | 1137.59 |
| 2029 | 1340.25 | 933.61 | 1136.93 |
| 2030 | 1339.58 | 932.94 | 1133.26 |

Table 3: Forecasted future rainfall in mm with lower and upper 95% confidence interval from 2023 to 2030.

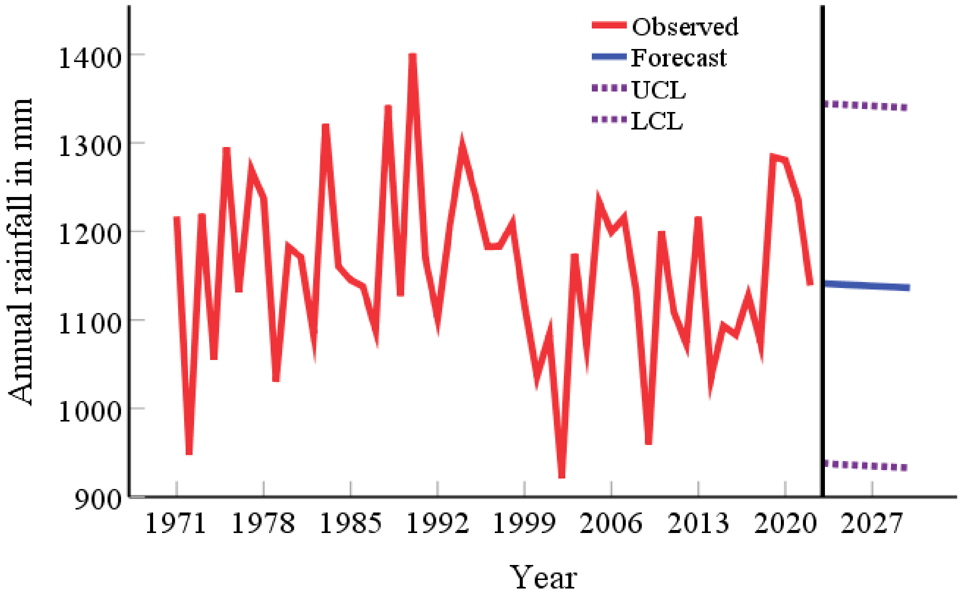



Figure 7: Annual rainfall forecast from the year 2023 to 2030. The red line represents observed rainfall from 1971 to 2022, the blue line represents the forecasted value from 2023 to 2030, and the dotted lines represent the upper and lower control limits.

Figure 7 illustrates the annual rainfall forecast from 2023 to 2030, where the red line signifies the observed rainfall data from 1971 to 2022. The forecasted trend indicates a consistent decrease in annual rainfall. While the ARIMA(1,0,0) model has been used to forecast rainfall patterns, it's important to acknowledge potential shortcomings. ARIMA models are linear and may not account for more complex and non-linear relationships in the data, such as the impact of climate change or other external factors. To improve forecasting accuracy, it may be advisable to explore other methods, such as machine learning models, that can handle more intricate relationships and incorporate additional variables to better capture the underlying dynamics of rainfall patterns. Additionally, considering the potential influence of exogenous variables and employing more advanced time series techniques could lead to more robust and accurate forecasts, particularly in the context of evolving climate patterns.

# 4 Conclusion

The primary objective of this study has involved the examination of rainfall trends in India, their impacts on agriculture, tourism, and economic growth, and further, forecasting the annual rainfall for the period spanning from 2023 to 2030. In this pursuit, both the Mann-Kendall test and the Sen's slope estimator have been utilized for the assessment of annual and seasonal rainfall patterns. A negative trend has persisted throughout the winter season from 2001 to 2022, whereas robust positive trends have emerged in the context of the pre-monsoon, monsoon, and post-monsoon seasons during the same timeframe. Conversely, annual rainfall has been found to exhibit a sustained, downward trajectory. The most substantial negative slope magnitude has materialized in the annual rainfall pattern (-1.0891 mm/year), while the most pronounced positive trend slope has been noted in the monsoon season (3.2538 mm/year). It is noteworthy that the southwest monsoon, prevailing from June to September, has significantly contributed to approximately 76% of India's total rainfall, with the highest recorded precipitation volume documented in 2019, and the lowest recorded in 2002.

The present study consistently pointed to a positive yet statistically insignificant relationship between annual rainfall and per-capita domestic product. Similarly, a statistically insignificant correlation has been discerned between annual rainfall and the number of tourists. Conversely, a robust and positive correlation between annual rainfall and foodgrain production has been observed and was found to be statistically significant. Additionally, the current study entailed the provision of forecasts regarding rainfall in India for the upcoming eight-year period, extending from 2023 to 2030. These forecasts, facilitated by the application of the ARIMA(1,0,0) model, have consistently projected a continuing decline in annual rainfall. This projected reduction in rainfall could entail severe ramifications for critical aspects such as water resources, agricultural productivity, and the overall economy. Consequently, proactive measures, encompassing water conservation initiatives, the adoption of drought-resistant agricultural practices, and investments in alternative energy sources, are deemed imperative.

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