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**Research Article**

# TREND ANALYSIS AND PREDICTION OF RAINFALL AND TEMPERATURE USING MANN-KENDALL, SEN'S SLOPE AND SARIMA MODEL IN NORTH WEST AGRO CLIMATIC ZONE OF TAMIL NADU

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## ABSTRACT

The United Nation's Global Sustainable Development Goal 13 is framed for taking urgent action to combat climate change and its impacts. Tamil Nadu stands with a composite score of 67 under the Performance towards SDG's goals in 2022-23.Since studies made at regional level would contribute to the national focus on achieving the goal, an attempt is made to study the trend analysis and prediction of Rainfall and Temperature using Mann-Kendall, Sen's Slope and SARIMA model in North West Agro Climatic Zone, Tamil Nadu. This study would assist the policy and decision-makers to establish strategies to combat the changes in rainfall and temperature patterns and their stress on the global climatic change.



## INTRODUCTION

Climate change is already an established fact and the intensity and frequency of the changes in climate extremes and their impacts on a variety of physical and biological systems contribute to global warming (IPCC 2007). Climate change worsens poverty, elevates food insecurity, increases health risks and therefore escalates the overall vulnerability of exposed people(UN Fact Sheet 2010).Climate change has become one of the most essential concerns in the field of sustainable development, and its impacts can be felt in different parts of the globe (Dioha and Kumar 2020) and it can also drag societies towards social tipping points like-forced migration, and chronic poverty (Vaibhav Bangar *et al*. 2020).

The United Nation's Global Sustainable Development Goal 13 is framed for taking urgent action to combat climate change and its impacts (UN Summit 2015). The overall commitment made by the UN was to achieve Goal 13 in an integrated manner focusing on three broad areas- economy, society, and environmentand the goal is aimed at integrating climate change measures, disaster risk measures and sustainable natural resource management into national development strategies (SDG Index and Dashboard 2022-23). The understanding of past and recent climate change has received considerable attention through improvements and extensions of numerous datasets and more sophisticated data analyses across the globe (Kumar *et al*. 2010).Recent progress has demonstrated that synergistic blending of data from gauge stations and remote sensing satellites data can reliably present the spatial-temporal distribution of rainfall over extensive areas (Maidment *et al*. 2017).Hence an attempt is made to study the trend analysis and prediction of Rainfall and Temperature using Mann-Kendall, Sen's Slope and SARIMA model in North West Agro Climatic Zone, Tamil Nadu, India.

## Objectives

- To analyze the Coefficient of Variability for Rainfall and Temperature from 1981 to 2020.
- To study the Trend of Rainfall and Temperature from 1981 to 2020.
- To Predict the Rainfall and Temperature in the study area.
- To list the Action Plans for SDG 13-Action to Combat Climate Change- those are in progress and undertaken by the Government of Tamil Nadu.

### Study Area

The classification of agro climatic zones in India was made in the 1990's for identifying priorities and developing strategies for location-specific and need-based research as well as overall agricultural development in the country and long-term climatic parameters, particularly temperature and rainfall along with soil

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and crop information were used for the classification of agro climatic zones (Chattopadhyay *et al*. 2019).Tamil Nadu has been classified into seven Agro Climatic Zones based on soil characteristics, rainfall distribution, irrigation pattern, cropping pattern and other social characteristics (TNAU, 2013).

The zone chosen for the present study is the North West AgroClimatic Zone of Tamil Nadu. The study area comprises the revenue districts of Dharmapuri, Krishnagiri, Salem and Namakkal. The study area is situated between 11 and $12^0$55' north latitude and $77^0$28' and $78^0$50' east longitude ( Fig.. 1). The study area covers a total geographical area of 17490.4 sq km,out of which 8000 sq.km are under cultivation. This zone receives rainfall from South West and North West monsoon seasons, with an average annual rainfall of 878 mm. The average temperature ranges from a maximum of 20°C to 42°C to a minimum of 10°C to 31°C. Paddy, Maize, Ragi, Cumbu, Tapiaco and Sugarcane are the major crops cultivated in the study area.

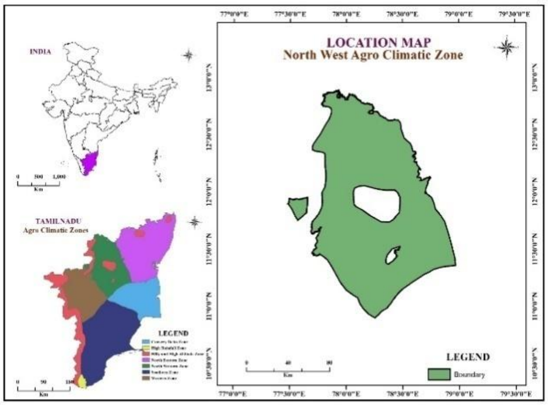


**Fig..1** North West Agro Climatic Zone of Tamil Nadu

## METHODOLOGY AND DATA

The rainfall data is downloaded from NASA/POWER CERES/MERRA2 Native Resolution Monthly and Annual from 1981 to 2020, with 0.5*0.625 degree at approximately 284.14 meters. The gridded rainfall data is collected from 46 grids located in and around the study area. Temperature data is downloaded from the same platform from 1981 to 2020and the data range is 2 meters. The software Arc GIS 10.3 and Microsoft Office 2010 is used to process and compute the data. The Coefficient of Variability of both climatic variables are calculated using simple statistical techniques. R CRAN algorithm is used to analyze the Trends using Mann-Kendall and Sen's Slope tests. The Dickey Fuller Test and SARIMA Model are used to predict the rainfall and temperature in the study area.

**Review of Literature**

***Previous studies using Coefficient of Variabilityin Rainfall and Temperatureanalysis***

The Co-efficient of Variation (CV) represents the ratio between standard deviation and mean and it is used to compare the degree of variation from one data series to another and a higher value of CV is the indicator of larger variability, and vice versa (Abha Sinha *et al*. 2019). The coefficient of variation for annual, SW monsoon, NE monsoon, winter and summer season is analyzed for different time series in Shillong and Agartala stations located in the north-east region of India (Mirbana *et al*. 2020). The trend, variability, intensity, number of dry days, mean rainfall pattern and variability in annual and SW monsoon season between 1989 to 2018, is analyzed, district wise, for Kerala and West Bengal, (Observed Rainfall Variability and Changes over Kerala State and West Bengal 2020). The analysis of the spatiotemporal annual rainfall variability in the Wadi Cheliff Basin, Algeria over the Period 1970 to 2018 shows an inverse spatial pattern between CV and the annual rainfall (Mohammed Achite *et al*. 2021).

***Previous studies in Trends of Rainfall and Temperature analysis using Mann-Kendall and Sen's Slope***

The Mann–Kendall (MK), a non-parametric test is used to detect an upward or downward trend in a series of hydrological climatic and environmental data (Zinabu *et al*. 2020). AgossouGadedjisso *et al*. (2021) analyzed the trend of climatic variables between the years 1977 to 2012 in 4 rain gauge stations, Togo, Africa, using MK test. A rainfall trend (1950–2015) is found significant on a seasonal basis for a southernmost river catchment in Western Ghats (Mudbhatkal and Amai 2018).

The Sen's estimator is a non-parametric method used for the trend analysis of hydroclimate data set and has been utilized for detecting trend in meteorological, hydrological and environmental variables (Sen 1968, 2012, 2014). Kuriqi *et al*.(2020) applied the MK methodology to validate findings from Sen's slope trend analysis in a study on the seasonality shift and stream flow variability trends in India. Annie Jenifer and Madan (2021) used MK and Sen test to assess the precipitation trends and its implications in the semi-arid region of Southern India. Similar studies are done for 21 stations for the period 1991-2020 in Mandya, Karnataka (Madhusudhan *et al*.2021).

***Previous studies in Prediction of Rainfall and Temperature***

The trend analysis facilitates to understand the present and past climatic changes, but the future forecasting is more useful for the planners to execute the proper planning considering future changes in climatic variables (Pandey *et al*. 2018). A study on the climate variables using SARIMA approach describes investigation of time series and seasonal analysis of the monthly mean minimum and maximum temperatures and the precipitation for the year 1901-2000 in the Bhagirathi river basin, Uttarakhand, India (Tripti Dimri *et al*. 2020). The SARIMA model and Dickey Fuller test were recommended as veritable techniques that will assist decision and policymakers to establish better strategies on the management of rainfall against upcoming weather changes to ensure increase in agricultural yields for the betterment of the citizens and general economic growth (Onyeka-Ubaka *et al*. 2021).

## RESULTS AND DISCUSSION

***Coefficient of Variability analysis for Rainfall and Temperature in North West Agro Climatic Zone of Tamil Nadu***

In this study, the monthly, annual, and seasonal rainfall and temperature variability were computed using Coefficient of Variability (CV). A higher value of CV is the indicator of larger variability, and vice versa which is computed as- CV= $\sigma/\mu$ x 100, where = $\sigma$ is the standard deviation and $\mu$ is the mean precipitation (Amogne Asfaw *et al*. 2018).

***Coefficient of Variability analysis forMean Monthly Rainfall and Temperature***

The Coefficient of Variability for mean monthly rainfall and temperature from 1981 to 2020, for 46 grids, in North West agro climatic zone is shown in Fig..2 and 3. The Coefficient of Variability is computed using IDW interpolation method, a geo-statistical approach (Bushra Praveen *et al*. 2020). The findings of spatial mapping of rainfall variation, from Fig.. 2 shows that the highest rainfall fluctuation is noticed during the months of February, March, and January. The lowest rainfall fluctuations are recorded in the months of August, September, and October. From Fig.. 3, it could be observed that the spatial mapping of temperature variation, shows a highest fluctuation during the month of June followed by almost all the months which have experienced a highest fluctuation other than February and January, which have the lowest temperature fluctuations, in the study area.

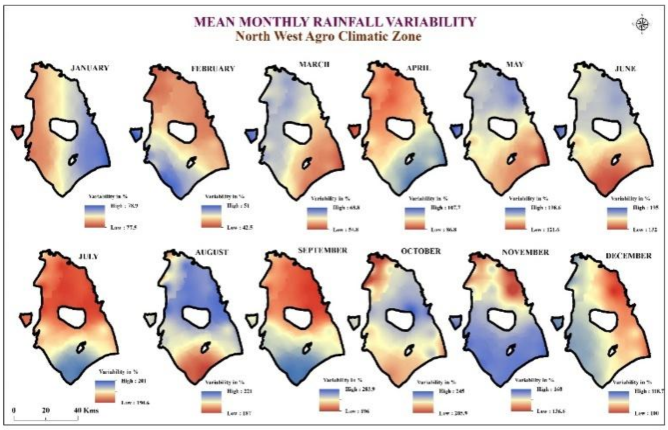


**Fig..2** Mean Monthly Rainfall Variability from 1981-2020 in North West Agro Climatic Zone, Tamil Nadu

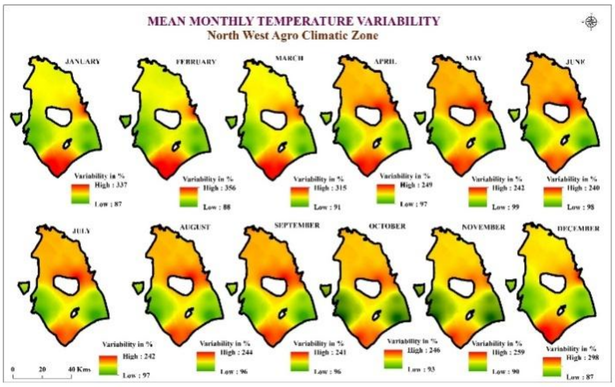


**Fig..3** Mean Monthly Temperature Variability from 1981-2020 in North West Agro Climatic Zone, Tamil Nadu

***Coefficient of Variability analysis for Mean Seasonal Rainfall and Temperature***

The Coefficient of Variability for mean seasonal rainfall and temperature from 1981 to 2020, for 46 grids, in North West agro climatic zone is shown in Fig..4 and 5. The Fig.. 4 shows that during the summer season, a highest fluctuation of rainfall is noticed in the major areas of south, south eastern and a few areas in the north. During winter, the rainfall fluctuation is higher in the majority regions of the study area. While in south west and north east monsoon seasons, the higher rainfall fluctuations are noticed in south and North West areas, respectively. The Fig.. 5 depicts that almost in all the seasons, a highest fluctuation of temperature is noticed in the south western and south eastern parts of the study area. And the remaining areas have experienced the lowest fluctuations in temperature in all the seasons.

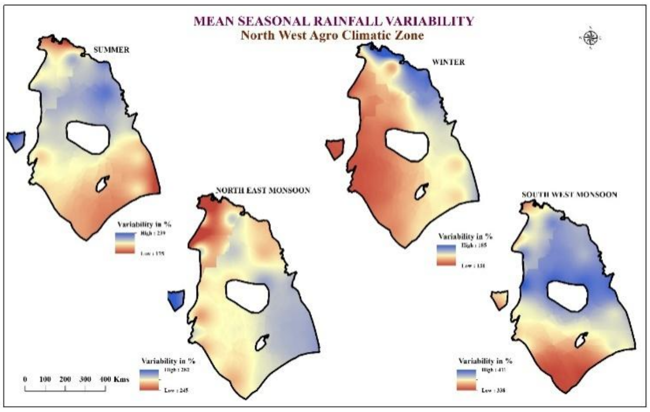


**Fig..4** Mean Seasonal Rainfall Variability from 1981-2020 in North West Agro Climatic Zone, Tamil Nadu

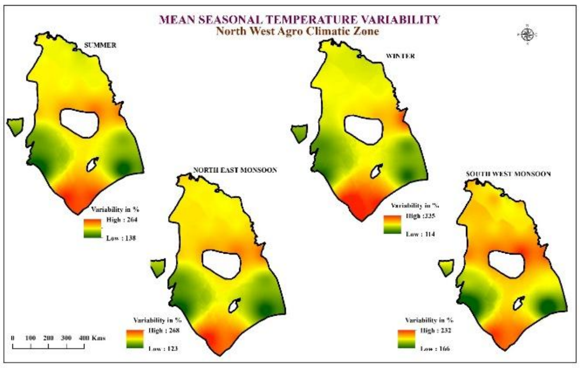


**Fig..5** Mean Seasonal Temperature Variability from 1981-2020 in North West Agro Climatic Zone, Tamil Nadu

***Coefficient of Variability analysis for Mean Annual, Pre and Post Monsoon Rainfall and Temperature***

The Coefficient of Variability for mean annual, pre and post monsoonrainfall and temperature from 1981 to 2020, for 46 grids, in North West agro climatic zone is shown in Fig..6 and 7.From Fig.. 6, it could be understood that a highest fluctuation of rainfall is noticed during the post monsoon season, when compared with annual and pre monsoon seasons andthe Fig.. 7 demonstrates that a highest fluctuation of temperature is noticed during the post monsoon season, when compared with annual and pre monsoon seasons, in the study area.

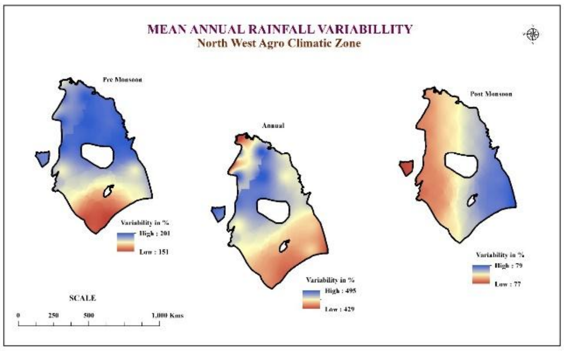


**Fig..6** Mean Annual, Pre and Post Monsoon Rainfall Variability from 1981-2020 in North West Agro Climatic Zone, Tamil Nadu

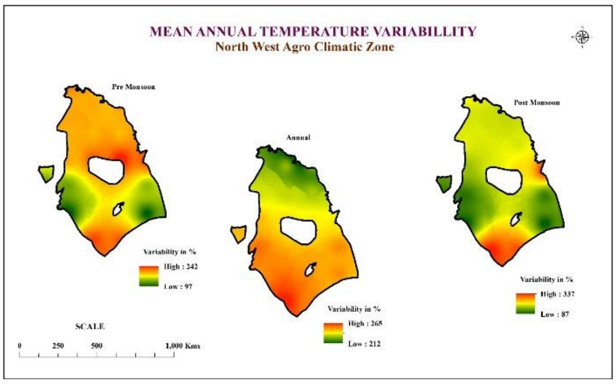


**Fig..7** Mean Annual, Pre and Post Monsoon Temperature Variability from 1981-2020 in North West Agro Climatic Zone, Tamil Nadu

### *Trend analysis for Rainfall and Temperaturein North West Agro Climatic Zone of Tamil Naduusing Mann-Kendall and Sen's Slope*

The trend of rainfall and temperature is analyzed in the study area from 1981 to 2020, for 46 grids, using Mann-Kendall and Sen's slope tests.

### *Trend analysis for Monthly, Seasonal, and Annual Rainfall and Temperature*

The Tables 1 and 2, presents the monthly, seasonal,and annual rainfall and temperature patterns obtained in the study areausing Mann-Kendall test and the slope estimator from Sen. While running Mann-Kendall test, Kendall Tau, a measure of correlation between two variables, is obtained. Kendall tau will take values between ± 1.

**Table 1** Monthly, Seasonal and Annual Rainfall trend analysis results with Significance level (α) = 5%

| Months | Z Score | Var S | Mann Kendall Tau | P-value | Sen's Slope |
|---|---|---|---|---|---|
| January | -0.2563 | 7365.67 | -0.0295 | 0.7977 | -0.0007 |
| February | 0.7467 | 7346.33 | 0.0841 | 0.4552 | 0.0002 |
| March | 0.06992 | 7363.67 | 0.00899 | 0.9443 | 0.0003 |
| April | 1.2467 | 7366.67 | 0.1385 | 0.2125 | 0.0148 |
| May | 2.5283 | 7366.67 | 0.2795 | 0.0115 | 0.0419 |
| June | 0.45439 | 7366.67 | 0.0513 | 0.6495 | 0.0034 |
| July | 0.20973 | 7365.67 | 0.0244 | 0.8339 | 0.0033 |
| August | 1.3632 | 7366.67 | 0.1513 | 0.1728 | 0.0213 |
| September | -0.6525 | 7365.67 | -0.0731 | 0.5141 | -0.0131 |
| October | 1.1535 | 7366.67 | 0.1282 | 0.2487 | 0.0251 |
| November | 1.2467 | 7366.67 | 0.1385 | 0.2125 | 0.0331 |
| December | 0.1515 | 7366.67 | 0.0179 | 0.8796 | 0.0022 |
| Winter | 0.05826 | 7364.67 | 0.0077 | 0.9535 | 0.0002 |
| Summer | 2.4118 | 7366.67 | 0.2667 | 0.0159 | 0.0188 |
| SW Monsoon | 0.12816 | 7366.67 | 0.0154 | 0.898 | 0.0017 |
| NE Monsoon | 1.0602 | 7366.67 | 0.1179 | 0.289 | 0.0176 |
| Annual | 1.2234 | 7366.67 | 0.1359 | 0.2212 | 0.0077 |

**Table 2** Monthly, Seasonal and Annual Temperature trend analysis results with Significance level (α) = 5%

| Months | Z Score | Var S | Mann Kendall Tau | P-value | Sen's Slope |
|---|---|---|---|---|---|
| January | -5.3012 | 7366.67 | -0.5846 | 0.000 | -0.4887 |
| February | -4.8352 | 7366.67 | -0.5333 | 0.000 | -0.4830 |
| March | -4.7886 | 7366.67 | -0.5282 | 0.000 | -0.5599 |
| April | -4.9051 | 7366.67 | -0.5410 | 0.000 | -0.6546 |
| May | -4.7187 | 7366.67 | -0.5205 | 0.000 | -0.7073 |
| June | -4.1361 | 7366.67 | -0.4564 | 0.000 | -0.6465 |
| July | -5.2779 | 7366.67 | -0.5821 | 0.000 | -0.6690 |
| August | -4.7653 | 7366.67 | -0.5256 | 0.000 | -0.6193 |
| September | -4.6721 | 7366.67 | -0.5154 | 0.000 | -0.6269 |
| October | -5.1614 | 7366.67 | -0.5692 | 0.000 | -0.5913 |
| November | -4.9284 | 7366.67 | -0.5436 | 0.000 | -0.5249 |
| December | -5.3944 | 7366.67 | -0.5949 | 0.000 | -0.4802 |
| Winter | -5.1381 | 7366.67 | -0.5667 | 0.000 | -0.4579 |
| Summer | -5.1847 | 7366.67 | -0.5718 | 0.000 | -0.6130 |
| SW Monsoon | -4.8119 | 7366.67 | -0.5308 | 0.000 | -0.6116 |
| NE Monsoon | -5.4410 | 7366.67 | -0.6000 | 0.000 | -0.5259 |
| Annual | -5.8605 | 7366.67 | -0.6462 | 0.000 | -0.5407 |

From Table 1, the results based on the intensity of z value of Mann-Kendall test at 0.05 significance level indicates that the monthly rainfall shows a negative trend (0 to -1) during January and September.

The z value with a positive trend, varying from 0 to 2, is noticed for 9 months, and a highly positive trend (z value above 2) is found in May. Sen's slope test reveals an increasing trend (0.0002 to 0.0419) for 10 months and a decreasing trend, -0.0007 and -0.0131, in January and September respectively. The results of Mann-Kendall Tau and Sen's slope test of seasonal and annual rainfall shows a positive trend, in the study area. The results of the rainfall trend have shown an increase with significant trends observed at the 95% confidence levels.

From Table 2, it could be observed that the results of Mann-Kendall and Sen's slope tests proves that the monthly, seasonal and annual temperature has shown a negative trend, observed at the 95% confidence level, in the study area. The annual data trend is decreasing as both the slope estimator of the Sen and the tau (Z) values of Kendall were negative and found to be -0.5407 and -5.8605 respectively.

***Prediction analysis for Rainfall and Temperature in North West Agro Climatic Zone of Tamil Nadu using SARIMA Model***

The Box Jenkins (1976) advanced the ARIMA model and uses ARIMA time series models to systematically Identify, Estimate, and Check (goodness of fit) procedures. In the Identifying procedure, the ACF and PACF plots are used. The second procedure estimates the parameters of the identified models. The third procedure helps to assess the most fitted model using Ljung Box Test. Finally, the best-fitting model is chosen depending on the Akaike Information Criterion (AIC) value.

ARIMA (Auto Regressive Integrated and Moving Average) is an extensively used statistical tool to analyze and predict time series data and consider serial correlation within the time seriesand used to initiate forecasts (Yurekli etal. 2007). This approach is typically useful for short to medium-term forecasting (Jasan Brownlee 2020). A set of data obtained sequentially over time is called a Time series. Box Jenkins formula (Table 3) is applied (Paul Andrew Panga *et al*. 2020)to generate a pattern and structure of the time series data collected and examine the best-fit model and forecast.

**Table 3** Box Jenkins Algorithm

| |
|---|
| 1. Plot series. |
| 2. Is variance stable? |
| 2a. No, Apply Transformation, go to 1. |
| 2b. Yes, continue. |
| 3. Obtain ACFs and PACFs. |
| 4. Is mean stationary? |
| 4a. No, Apply Regular and Seasonal differencing. |
| 4b. Yes, continue. |
| 5. Model Selection. |
| 6. Estimate Parameter Values. |
| 7. Are Residuals Uncorrelated? |
| 7a. No, Modify Model, go to 5. |
| 7b. Yes, continue. |
| 8. Are Parameters Significant and Uncorrelated? |
| 8a. No, Modify Model, go to 5. |
| 8b. Yes, continue. |
| 9. Forecast. |

The first step is to plot the data, and as it occurs in time, it is called a time plot. The time series plot for both the climatic factors are calculated from 1981 to 2020 and is shown in-monthly rainfall ( Fig.ure 8) and temperature ( Fig.ure 9- Non-Stationary) and ( Fig.ure10-Stationary). From the Fig.ures, it could be observed that the time series plot for rainfall and temperature, which are volatile, is an indication of seasonality. The series generally shows the rise and fall of monthly precipitation and temperature in the study area over the years.

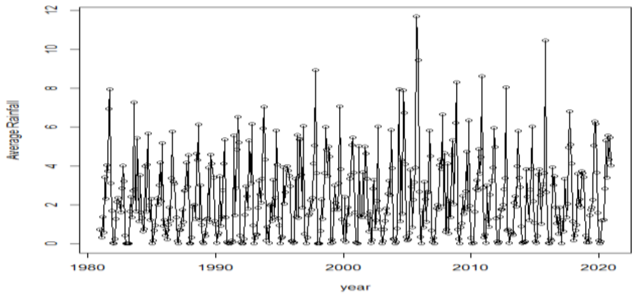


**Fig.. 8** Time series plot for monthly rainfall (Stationary)

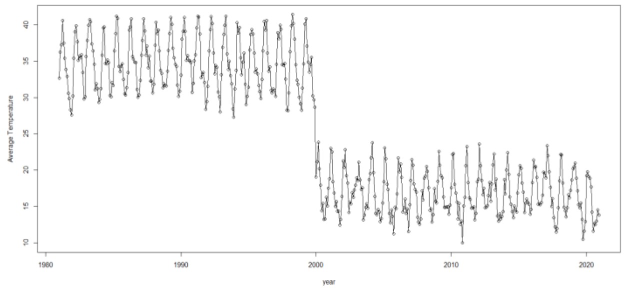

**Fig.. 9** Time series plot for monthly temperature (Non Stationary)

We can endorse the non-seasonality behavior to select the best-fit model by computing the Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF). As the model selection is vital, and to achieve it, the analysis of ACF and PACF needs to be appropriately applied and the ACF and PACF plots for rainfall and temperature in Tables 4 and 5, respectively.

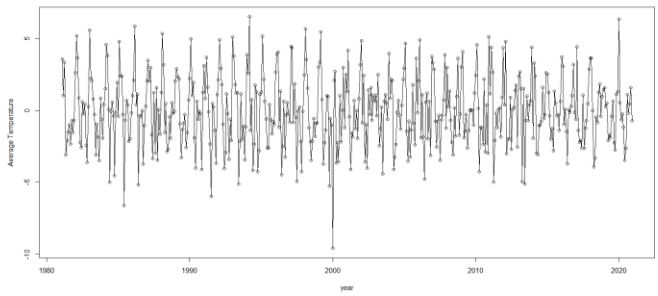

**Fig.. 10** Time series plot of monthly temperature (Stationary)

**Table 4** ACF and PACF plots for monthly rainfall

| Lag | ACF | PACF | Lag | ACF | PACF |
|---|---|---|---|---|---|
| 1 | .446 | .446 | 25 | .387 | -.024 |
| 2 | .158 | -.052 | 26 | .146 | -.049 |
| 3 | -.092 | -.180 | 27 | -.076 | -.009 |
| 4 | -.251 | -.173 | 28 | -.206 | .015 |
| 5 | -.303 | -.132 | 29 | -.263 | .018 |
| 6 | -.307 | -.148 | 30 | -.279 | -.011 |
| 7 | -.292 | -.183 | 31 | -.314 | -.074 |
| 8 | -.248 | -.187 | 32 | -.228 | .054 |
| 9 | -.139 | -.126 | 33 | -.090 | .035 |
| 10 | .119 | .099 | 34 | .152 | .059 |

| | | | | | |
|---|---|---|---|---|---|
| 11 | .382 | .223 | 35 | .356 | .009 |
| 12 | .518 | .236 | 36 | .487 | .052 |
| 13 | .448 | .149 | 37 | .421 | .113 |
| 14 | .144 | -.099 | 38 | .133 | -.073 |
| 15 | -.083 | -.062 | 39 | -.101 | -.043 |
| 16 | -.265 | -.105 | 40 | -.251 | -.084 |
| 17 | -.276 | .019 | 41 | -.281 | -.017 |
| 18 | -.294 | -.046 | 42 | -.263 | .066 |
| 19 | -.314 | -.104 | 43 | -.276 | .024 |
| 20 | -.256 | -.061 | 44 | -.264 | -.094 |
| 21 | -.091 | .027 | 45 | -.082 | .030 |
| 22 | .099 | -.003 | 46 | .166 | .084 |
| 23 | .430 | .221 | 47 | .357 | -.013 |
| 24 | .521 | .112 | 48 | .486 | .102 |

**Table 5** ACF and PACF plots for monthly temperature

| Lag | ACF | PACF | Lag | ACF | PACF |
|---|---|---|---|---|---|
| 1 | 0.23 | 0.23 | 25 | 0.31 | 0.10 |
| 2 | 0.02 | -0.04 | 26 | 0.07 | 0.07 |
| 3 | -0.15 | -0.15 | 27 | -0.17 | -0.05 |
| 4 | -0.27 | -0.21 | 28 | -0.25 | -0.10 |
| 5 | -0.20 | -0.11 | 29 | -0.14 | 0.01 |
| 6 | -0.14 | -0.11 | 30 | -0.18 | -0.05 |
| 7 | -0.21 | -0.26 | 31 | -0.18 | 0.01 |
| 8 | -0.26 | -0.35 | 32 | -0.24 | -0.05 |
| 9 | -0.15 | -0.29 | 33 | -0.10 | 0.04 |
| 10 | 0.06 | -0.20 | 34 | 0.07 | -0.04 |
| 11 | 0.35 | 0.04 | 35 | 0.30 | -0.06 |
| 12 | 0.50 | 0.22 | 36 | 0.50 | 0.12 |
| 13 | 0.35 | 0.19 | 37 | 0.30 | 0.05 |
| 14 | 0.04 | 0.02 | 38 | 0.05 | 0.01 |
| 15 | -0.14 | -0.01 | 39 | -0.17 | -0.06 |
| 16 | -0.20 | -0.02 | 40 | -0.21 | -0.03 |
| 17 | -0.19 | -0.04 | 41 | -0.22 | -0.10 |
| 18 | -0.14 | 0.01 | 42 | -0.10 | 0.03 |
| 19 | -0.22 | -0.05 | 43 | -0.17 | 0.04 |
| 20 | -0.23 | -0.04 | 44 | -0.22 | -0.01 |
| 21 | -0.16 | -0.10 | 45 | -0.09 | 0.05 |
| 22 | 0.08 | -0.05 | 46 | 0.06 | -0.03 |
| 23 | 0.34 | 0.03 | 47 | 0.31 | -0.01 |
| 24 | 0.49 | 0.16 | 48 | 0.45 | 0.04 |

The time series ACF and PACF plots for the monthly rainfall and temperature from 1981 to 2020 are observed, and the same is given in Fig.ures 11 and 12 respectively. From the Fig. 11, it could be observed that most of the spikes of ACF and PACF plots are outside the confidence limits. It is also seen that the ACF shows a wave-like pattern of variation. It offers a significant autocorrelation time series plot of monthly rainfall from January 1981 to December 2020 with *d* = 0 and *D* = 0. And the Fig.ure 12 shows that there is no significant autocorrelation time series plot of monthly temperature, with seasonal differencing.

### *Augmented Dickey-Fuller Test*

The Augmented Dickey-Fuller test (ADF), a unit root test (whether a time series is stationary or non-stationary), allows accepting or rejecting the null hypothesis of stationarity in a time series for validation and the same method (Yugesh Varma 2021) is used in the present study. The ADF test will give a negative number on which the rejection of the hypothesis depends.

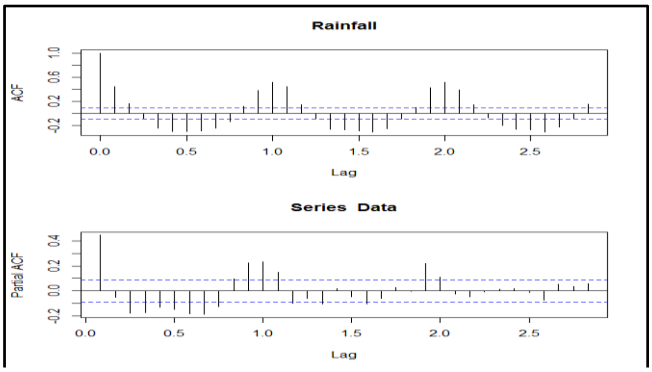


**Fig..11** Time series ACF and PACF plots for monthly rainfall with Seasonal Differencing

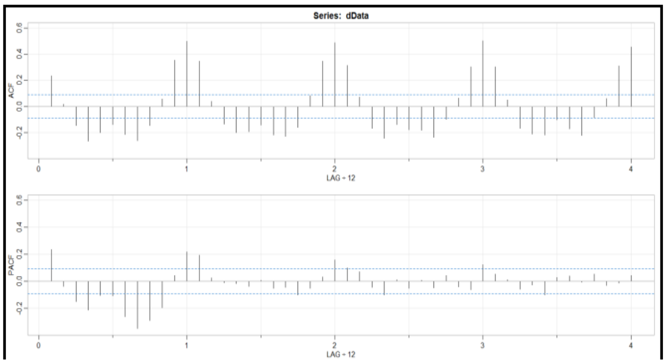


**Fig..12** Time series ACF and PACF plots for monthly temperature with Seasonal Differencing

This test uses two assumptions, the Null hypothesis, where the series is non-stationary, and the Alternative hypothesis, where the series is stationary (Vijaya Kumar 2021). In the present study, the same test is done using an algorithm designed using R programming software.

Stationarity plays an essential role in time series analysis,and one can test the stationarity or time series data using the unit root test proposed by Dickey and Fuller in 1979 (Erik Erhardt 2002).The authors (Rob Hyndman and George Athanasopoulos (2018), Dabraland Murry(2017), David Dickey and Wayne Fuller(1979)have used Duckey Fuller Test to forecast the rainfall pattern for the monthly weekly, and daily monsoon time series and the same methodology is used in this research.

### *Rainfall*

Data: Data
Dickey-Fuller = -13.865, Lag order = 7, p-value = 0.01
Alternative hypothesis is stationary
Test statistic is -13.865 and P-value is 0.01
Since the p-value is less than .05, it could be concluded that the Monthly Rainfall data is Stationary.

### *Temperature*

Augmented Dickey-Fuller Test
data: Data
Dickey-Fuller = -17.128, Lag order = 7, p-value = 0.01
Alternative hypothesis is stationary
Test statistic is -17.128 and P-value is 0.01
Since the p-value is greater than .05, hence, it could be concluded that the Monthly Temperature data is Stationary.

The time series plot of monthly temperature from the year 1981 to 2020 is shown in Fig. 13, and the results proves that the time series seems is stationary. The ACF and PACF plots for temperature. Fig. 14 shows that there is a significant autocorrelation time series plot of monthly Temperature from January 1981 to December 2020 with *d* = 1.

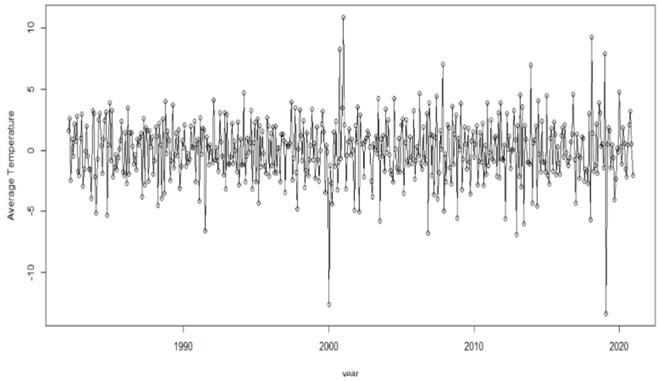


**Fig. 13** Time series plot for monthly temperature with Seasonal Differencing d = 1 and D = 1

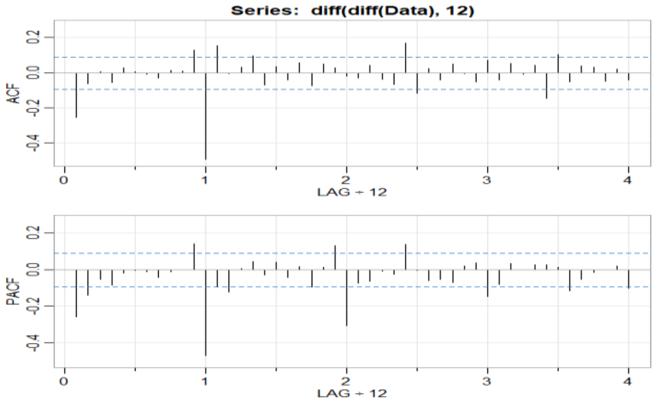


**Fig. 14** ACF and PACF plot for monthly temperature with Seasonal Differencing d = 1 and D = 1

### *Model Fit for Rainfall and Temperature*

The 8 Identified ARIMA models were listed in Table 6 and 7 for monthly rainfall and temperature data. It could be observed that only ARIMA $(1,0,1)(1,0,1)_{12}$with an AIC score of 1855.23, and ARIMA (1,1,1) $(1,1,1)_{12}$ with an AIC score of 1885.03 has met the assumptions of the model diagnostics, for rainfall and temperature.

**Table 6** Model Fit for monthly rainfall

| Model | AIC Value |
|---|---|
| **(1,0,1) $(1,0,1)_{12}$** | **1855.23** |
| (1,0,2) $(1,0,1)_{12}$ | 1856.78 |
| (1,0,1) $(1,0,2)_{12}$ | 1856.62 |
| (1,0,2) $(1,0,2)_{12}$ | 1858.23 |
| (1,0,0) $(1,0,0)_{12}$ | 1970.18 |
| (1,0,0) $(0,0,1)_{12}$ | 2004.73 |
| (0,0,1) $(1,0,0)_{12}$ | 1970.83 |
| (0,0,1) $(0,0,1)_{12}$ | 2006.48 |

**Table 7** Model Fit for monthly temperature

| Model | AIC Value |
|---|---|
| **(1,1,1) $(1,1,1)_{12}$** | **1885.03** |
| (1,1,1) $(1,1,2)_{12}$ | 1887.31 |
| (1,1,1) $(2,1,1)_{12}$ | 1886.91 |
| (1,1,2) $(1,1,1)_{12}$ | 1885.27 |
| (1,1,2) $(1,1,2)_{12}$ | 1887.42 |
| (1,1,2) $(2,1,1)_{12}$ | 1887.15 |
| (2,1,1) $(1,1,1)_{12}$ | 1885.48 |
| (2,1,1) $(1,1,2)_{12}$ | 1887.64 |

### *Residual Plot*

The residual plots of monthly rainfall and temperature data are shown in Fig. ures 15 and 16, respectively. The results shown in the Fig.ures are derived by following the method adopted by the Akpanta *et al*. 2015. The mean of the residuals is close to zero, and there is no significant correlation in the residual series in the study area. It can be observed from the Fig.ure that, in the Standardized Residuals, a sizeable positive residual is seen in 2006 for monthly rainfall and a negative residual is seen during 2000 for temperature, respectively. The time series showing a wave-like pattern is evidence of seasonality. The ACF of the residuals graph shows a periodic pattern that might be due to the seasonal effect. In this study, the Ljung-Box test (a test employed to check the independence of the residuals) is based on a Q-Q plot where the p-value is proportionately large.

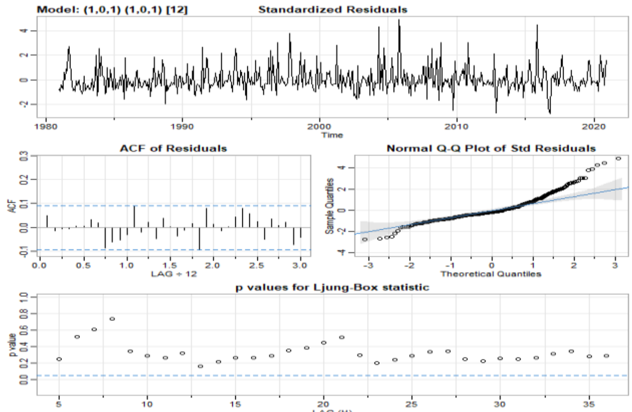


**Fig.15** Residual plots for monthly rainfall

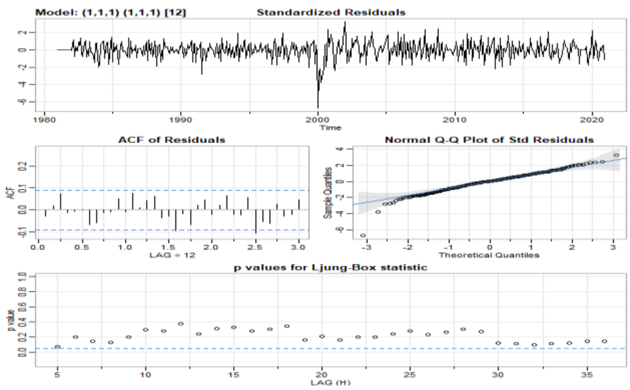


**Fig.16** Residual plots for monthly temperature

### *Forecast*

The term forecast refers to predicting the future monthly rainfall and temperature of the studied time series. Forecasting is vital in decision-making and planning processes in all socio-economic sectors. The best-fitting model based on AIC is selected. As per the suggestion bySamuel Olorunfemi Adams and Muhammad Ardo Bamanga (2020), the model with the smallest AIC, and the same procedure is followed in the present research study. The studydone by Michael Asamoah-Boaheng(2014), also supports that the selection of the best-fit model is strongly associated with the best performance of the residual analysis.

### *Rainfall*

Fig.ure 17 shows the forecasted series lies with the original time series data set. The predictive power of SARIMA $(1,0,1)(1,0,1)_{12}$ is very appreciable as it fits well to the test data. The selected models were considered to be the best model and is used to forecast the Rainfall for next Five years 2021, 2022,

**Table 8** Prediction for monthly rainfall

| Month | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|
| January | 0.4172892 | 0.3884051 | 0.3742679 | 0.3677043 | 0.3650300 |
| February | 0.4169539 | 0.3897052 | 0.3764069 | 0.3702731 | 0.3678184 |
| March | 0.5954364 | 0.5696037 | 0.5569678 | 0.5511095 | 0.5487318 |
| April | 1.3507286 | 1.3258049 | 1.3133657 | 1.3073384 | 1.3046040 |
| May | 2.5066959 | 2.4823082 | 2.4697313 | 2.4632205 | 2.4598254 |
| June | 2.1629606 | 2.1401348 | 2.1284815 | 2.1225667 | 2.1195990 |
| July | 2.6096328 | 2.5877180 | 2.5763726 | 2.5704558 | 2.5673273 |
| August | 3.1589028 | 3.1377568 | 3.1266097 | 3.1205982 | 3.1172248 |
| September | 4.2861969 | 4.2653323 | 4.2539270 | 4.2473808 | 4.2433306 |
| October | 4.9473289 | 4.9270277 | 4.9156756 | 4.9089203 | 4.9045268 |
| November | 4.2873181 | 4.2684934 | 4.2581341 | 4.2521231 | 4.2483460 |
| December | 1.8789872 | 1.8628683 | 1.8547563 | 1.8507566 | 1.8488688 |

2023, 2024 and 2025, and the black line indicates the actual values and the red line depicts the predicted values. Table 9 shows the prediction of monthly rainfall till 2025. It predicts that the rainfall will decline in the coming years.

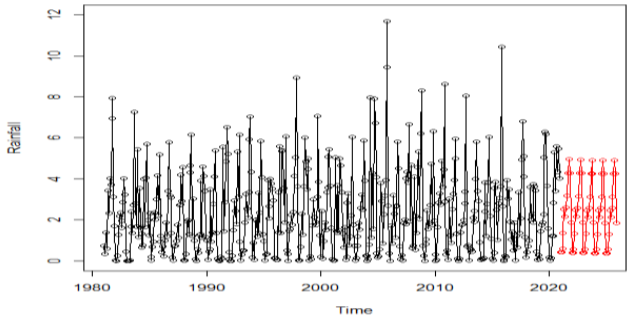


**Fig.17** Forcast plots for monthly rainfall

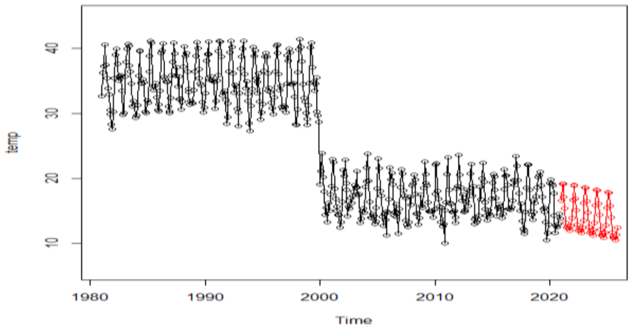


**Fig. 18** Forecast plotsfor monthly temperature

***Temperature***

Fig.ure 18 shows the forecasted series lies with the original time series data set. The predictive power of SARIMA (1, 1, 1) $(1, 1, 1)_{12}$ is very appreciable as it fits well to the test data. The selected model were considered to be the best model and is used to forecast the Temperature for next Five years 2021, 2022, 2023, 2024 and 2025, and the black line indicates the actual values and the red line depicts the predicted values. Table 9 shows the prediction of monthly temperature till 2025. It predicts that the temperature will decline in the coming years.

**Action Plans towards SDG 13-Climate Change undertaken by the Government of Tamil Nadu**

**A. The Centre for Environmental Information System (ENVIS 2019), Tamil Nadu,has taken steps to combat climate change and those following.**

1. TamilNadu State Climate Change Cell (TNSCCC)

   Realizing the importance of the impact of climate change, the Department of Environment (DoE), Government of Tamil Nadu has initiated Tamil Nadu State Climate Change Cell (TNSCCC) responding to the call of India's National Action Plan on Climate Change (NAPCC). The vision of the cell is to respond to global climate change by building capacity at the local level, particularly in the context of Tamil Nadu State, and to make it a resilient state to combat climate change.

**Table 9** Forecast for monthly temperature

| Month | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|
| January | 16.61454 | 16.63579 | 16.25217 | 15.88052 | 15.50848 |
| February | 19.15984 | 18.98945 | 18.61154 | 18.23971 | 17.86768 |
| March | 19.16446 | 18.89600 | 18.52099 | 18.14906 | 17.77704 |
| April | 17.10832 | 16.84922 | 16.47382 | 16.10191 | 15.72988 |
| May | 15.41710 | 15.14627 | 14.77118 | 14.39925 | 14.02723 |
| June | 13.18117 | 12.85544 | 12.48203 | 12.11005 | 11.73803 |
| July | 12.40915 | 12.01551 | 11.64420 | 11.27215 | 10.90013 |
| August | 12.65414 | 12.28111 | 11.90914 | 11.53712 | 11.16510 |
| September | 12.36035 | 11.9817 | 11.61520 | 11.24317 | 10.87115 |
| October | 11.93090 | 11.58283 | 11.21007 | 10.83807 | 10.46605 |
| November | 12.75292 | 12.42743 | 12.05396 | 11.68198 | 11.30996 |
| December | 13.94765 | 13.56124 | 13.18967 | 12.81763 | 12.44561 |

This will be addressed through effective climate change governance and climate services by connecting climate change science- policy-society by the climate change cell. However, the cell's mission is to establish a platform to collect, collate and disseminate climate change information about Tamil Nadu State to various stakeholders ranging from farmers, fishermen, the general public to policy planners, decision-makers, bureaucrats, and others to enable effective climate change governance and services.

2. Climate Change Adaptation in Rural Areas of India (CCARAI) Project

CCARAI is an Indo-German development project that aims to strengthen the efforts of rural communities in India to cope with climate variability and change. The project has different components, such as preparing action plans on climate change, vulnerability, and risk assessments, climate adaptation measures, climate-proofing public investments,financial instruments for adaptation, information on knowledge management, and human capacity building.

3. State Action Plans on Climate Change (SAPCC)

This would help identify measures that promote development objectives while yielding co-benefits for addressing climate change effectively and outlines the particular regional and local characteristics and specific concerns of vulnerable sectors and communities within each State.

**B. The Government of Tamil Nadu State Action Plan on Climate Change (TNSAPCC) (Department of Environment and Climate Change, 2022) has initiated adaptation strategies regarding the Sustainable Development Goal 13-Climate Action, to achieve targets 13.1, 13.2, and 13.3. Those include:**

1. Tamil Nadu Green Climate Company (TNGCC) is framed to catalyze public and private financing to implement climate actions. This provides incremental funding for exclusive climate adaptation and mitigation actions and forging partnerships and capacities to implement such measures effectively.
2. The National Adaptation Fund for Climate Change (NAFCC) on Coastal Area Management is framed to assess vulnerability to climate change on coastal ecosystems and coastal communities.
3. Promotion of Electric Vehicles for public and private transport has been another approach to moving towards renewable energy sources to improve climate resilience.
4. Promotion of Green spaces and protection of Wetlands are some of the other interventions initiated by the State that are closely linked to climate resilience.
5. The Department of Environment and Climate Change works to formulate Early Warning Systems to reduce the impact of extreme weather events. The State will move closer to the Target of "0" as determined by the National Indicator Framework to strengthen the resilience and adaptive capacity to climate-related hazards and natural disasters.
6. The State focuses on developing Early Warning Systems and Risk Management to monitor climate shocks.
7. The Government of Tamil Nadu has taken the initiative to set up an exclusive Climate Change Research Center, "The Centre for Climate Change and Adaptation Research (renamed as Centre for Climate Change and Disaster Management (CCCDM), to strengthen the understanding of climate change and our capacity to manage and adapt to it. The Climate Studio is one of its kind, established with a high-performance computation facility cluster with storage and accessories for climate modeling at the district and blocks level.
8. Tamil Nadu Government started the Eco clubs - National Green Corps (NGC), the first of its kind in India. This program imparts environmental awareness to school students through on-campus and community activities like awareness programs, tree planting, celebrating Green Days, eco competitions, eco camps, etc., The NGC Eco clubs will also help and support the creation and maintenance of nutri-gardens in the schools with native species of trees and local vegetables wherever possible.
9. Chief Minister's Green Fellowship Programme (CMGFP) aims to disseminate climate change awareness by means and ways to attract younger generations and students and to create a pool of green ideas and technological interventions that will reduce the Environment, Climate change impacts, and conserve Nature.
10. The Climate Smart Villages would serve as demo sites to test an approach through participatory methods with various technological and institutional options for dealing with climate change at the community level. [81]
11. Sustainable Habitat–Energy saving measures in Government and Private buildings, residents–independent, and apartments are practiced to reduce greenhouse emissions from energy production and consumption to reduce the impacts of Climate Change.

## CONCLUSION

The present study analyzed the trend and predict the rainfall and temperature using Mann-Kendall, Sen's slope test and SARIMA model, for 46 grids, from 1981 to 2020 in North West Agro Climatic Zone of Tamil Nadu. The grid wise rainfall study using advanced remote sensing technology will be very useful for the micro level management planning in the study area.The present study provides information in all aspects like rainfall variability for rainfall and temperature and trend analysis for monthly, seasonal and annual rainfall. And the prediction of rainfall and temperature for the next 5 years are calculated in the study area. Technically, the present study has used techniques which have been admired worldwide by the scientists for providing high precision results. The basic and essential requirement for the management and developmental planning of any region in the recent times sectors is the exploration of the spatiotemporal distribution and of changing pattern of climatic variables. its trends and forecast. This study would be helpful to assist the policy and decision-makers to establish strategies and priorities to combat the changes in rainfall and temperature patterns in the study area and their stress on the global climatic change.

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