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RESEARCH ARTICLE

Trend and Prediction Analysis of Rainfall and Temperature in Dindigul District, Tamil Nadu, India

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ABSTRACT: Climate change is already a fact, where the intensity and frequency of changes in climate extremes and their impacts on various physical and biological systems contribute to global warming. The United Nations Global Sustainable Development Goal 13 calls for urgent action to address climate change and its impacts. The goals call for strengthening resilience and adaptive capacity at the national and local levels. Goal 13- Climate Action, is one of the nine goals for which India has shown a positive push. Tamil Nadu ranked second with a composite score of 74 and is listed as a Front Runner under the Performance towards SDG's goals in 2020-21. The National Action Plan on Climate Change Assessment declares that the climate parameter is important at the regional and local scale to estimate its impacts on various sectors. Hence in the present study, an attempt is made to analyze the trend and prediction of rainfall and temperature using statistical techniques like-Homogeneity test, Box and Whisker Plot test, Coefficient of Variability, Cluster Dendrogram, Mann-Kendall, Sen's slope, and ARIMA model in Dindigul district, Tamil Nadu, India. The rainfall and temperature data are collected from 15 rainfall stations spread across the district for 39 years, from 1981 to 2020. The results can help prioritize new strategies for managing available water resources to sustain the agriculture sector's dependence in the study area. The ongoing Action Plans of the Government of Tamil Nadu to achieve climate change mitigation measures are listed. These recommendations could be utilized by agriculturalists, agro-climatologists, and decision-makers to scientifically support development in the study area.
KEYWORDS: Environmental Sciences, Homogeneity, Box and Whisker Plot, Coefficient of Variability, Cluster Dendrogram, Mann-Kendall, Sen's slope, ARIMA.

Introduction

Climate change refers to a continuing shift in weather patterns, and although these may be natural, anthropogenic activities have been the primary cause of climate change since the 1800s.[1] The existence of climate change has already been proven, and the magnitude and occurrence of the variations in climate extremes and their control of various physical and biological systems argue for global warming.[2] Climate change exacerbates poverty, increases food insecurity and health risks, and thus escalates the overall vulnerability of exposed people.[3] It can also pull the community toward factors such as-forced displacement and chronic poverty,[4] and in the future, climate change will affect the agricultural zone and be the source of the threat of hunger and the increase of water scarcity.[5] Climate change has emerged as one of the most indispensable concerns in sustainable development[6], especially in the most vulnerable countries.[7] The United Nations Global Sustainable Development Goal 13 calls for urgent action to combat climate change and its impacts.[8] The overall commitment made by the UN is to achieve Goal 13 in an integrated manner focusing on three broad areas- Economic, Social, and Environmental. The goal is to incorporate climate change and disaster risk mitigation measures and sustainable natural resource management into national progress plans.[9] The goals call for strengthening resilience and adaptive capacity at the national level, as the chain reaction of climate change extends beyond national bounders.[9]

The highlights of deaths due to extreme weather events in 2018-19 said that, for every one crore population, 15 Indians lost their lives. Hence a target of zero was set, meaning that all States/Union Territories must be adequately prepared to ensure that no lives are lost due to extreme weather events.[9] The composite score for India has improved from 60 in 2019-20 to 66 in 2020-21, indicating that the country has made overall progress toward achieving the SDGs.[9] Nine targets are driving the positive push in India with a score between 65 and 99, with Goal 13- Climate Action, being one of them.[9] Tamil Nadu ranked second with a composite score of 74 and is listed as Front Runner under the Performance of States and Union Territory 2020-21.[9] The heatmap that displays the performance of each State/Union Territory shows that Tamil Nadu has achieved an Index score of 61, listed as a Performer, under SDG 13- Climate Action in 2020-21 and that the number of lives lost per 1 crore population due to extreme weather events is 12.85 in Tamil Nadu, in 2021-21.[9] Climate change is occurring on a global scale. Yet its impacts often vary from region to region. Local and regional level studies formulate the development plans that mitigate the fatal consequences of climate change,[10] and the perception of a climate emergency at the regional level has received much attention in the recent past.[11] Regional-level studies would help achieve the national level target, and assessment of climate parameters is important at the regional and local levels to estimate the impacts on differ-

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ent sectors, according to the National Action Plan on Climate Change.[12]

My mother is a geographer and, interestingly, does research in various areas of her field. In conversations with her, I learned facts about the current global focus on the Sustainable Development Goals. I was amazed to discern the 17 goals, of which Goal 13- Climate Action is closely related to the other SDGs. Goal 13 has five Targets, and each target includes one or more Indicators that can be used to measure and monitor global progress and challenges in achieving the goal. I have read in some articles that the United Nations and Non-governmental Organizations are working on issues related to UN SDG 13. And these details and statistics have always fascinated me.

I chose the study area, the Dindigul district, in Tamil Nadu, India, where my mother was born and where I often visited, especially the rainfall stations in the popular tourist hill station destinations -Berijam and Kodaikanal, where I did my primary education. At that time, I was curious to learn about the changes in the significant climatic variables- rainfall and temperature, in the Dindigul district. For this purpose, I wanted to collect the Rainfall and Temperature data for the study area and apply statistical techniques to analyze these data. It is at this point that I formulated my research question-

"How do climatic variables like Rainfall and Temperature affect climate change in a local area, and what mitigation measures could be taken to address it?"

My research would provide a valuable outcome for understanding climate change at the local level. In addition, I chose to incorporate the Government Action Plans currently being implemented in relation to SDG 13-Action, to combat climate change in the study area. The analysis of the differences in meteorological variables is an important task for the monitoring of climate change. Therefore, an attempt is made to analyze the trend and prediction of Rainfall and Temperature using statistical techniques like the Homogeneity test, Box and Whisker Plot test, Coefficient of Variability, Cluster Dendrogram, Mann-Kendall, Sen's slope, and ARIMA model in Dindigul district, Tamil Nadu, India.

Objectives:

1. To analyze the Uniformity and Variability of Rainfall and Temperature from 1981 to 2020.
2. To study the Pattern and Trend of Rainfall and Temperature from 1981 to 2020.
3. To Predict the Rainfall and Temperature in the study area.
4. 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 study area, Dindigul district, is located in the central part of Tamil Nadu, with an extension between 10°14'45" and 10°31'00" North latitudes and 77°45' and 78°4'30" East longitudes, covering an area of 6266.64 sq. Km (Figure 1). It is bordered by Erode, Karur, and Tiruchirappalli districts to the north, Madurai district to the east and south, Coimbatore district, and Kerala state to the west. Dindigul district is covered by an undulating plain predominantly with red soil.[13] The study area has a tropical climate, with an average annual temperature of 21.2°C and rainfall of about 700-1400 mm yearly. The population of the Dindigul district is 2159775 persons, according to the 2011 census, ranking 16th among the districts wise of Tamil Nadu.[14] The district is divided into fourteen blocks, namely Attur, Dindigul, Reddiyarchatram, Shanarpatti, Nattam, Nilakkottai, Vathalagundu, Oddanchatram, Palani, Toppampatti, Guziliamparai, Vadamadurai, Vedasandur, and Kodaikanal.

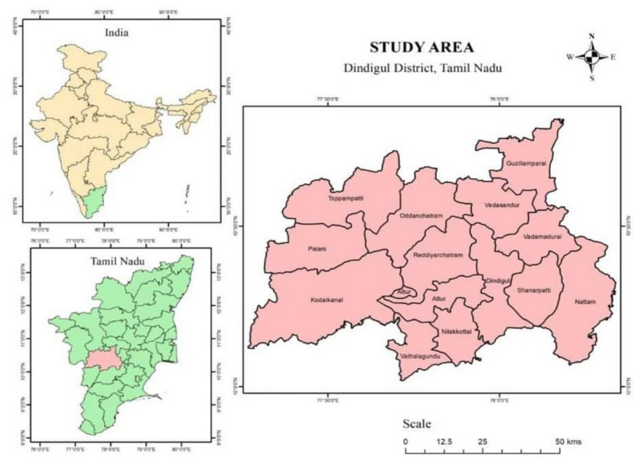

Figure 1: Study Area-Dindigul District.

Methodology and Data

The rainfall data were downloaded from NASA/POWER CERES/MERRA2 Native Resolution Average Monthly, from 01/01/1981 to 12/31/2020, with 0.5*0.625 degrees at approximately 706.32 meters. The rainfall data were collected from 15 rainfall stations for 39 years from 1981 to 2020 in the study area. The 15 rainfall stations are Berijam, Chatrapatti, Dindigul, Kamachipuram, Kodaganar, Kodaikanal, Kuthiraiyar Dam, Marudhanadhi Dam, Nattam, Nilakkotai, Palani, Peeranai, Vedasandur Central Tobacco Institute (CTRI), Vedasandur and Virupachi. The Average Monthly Temperature data were downloaded from the same platform from 01/01/1981 to 12/31/2020, and the data range is 2 meters. ArcMap 10.8 and Microsoft Office 2013 process and calculate the data. The location of the rainfall stations is shown in Figure 2: their latitudes, longitudes, and elevations are listed in Table 1. It is important to note that two hill stations, Berijam and Kodaikanal, are located in the study area. The Homogeneity test, Box and Whisker Plot test, Coefficient of Variability, and Cluster Dendrogram, for both climatic variables, were calculated using simple statistical techniques. Mann-Kendall and Sen's Slope tests analyze monthly rainfall and temperature trends. The precipitation and temperature data prediction analysis were analyzed using the Dickey-Fuller Test, and the ARIMA model was processed with R statistical R program software.

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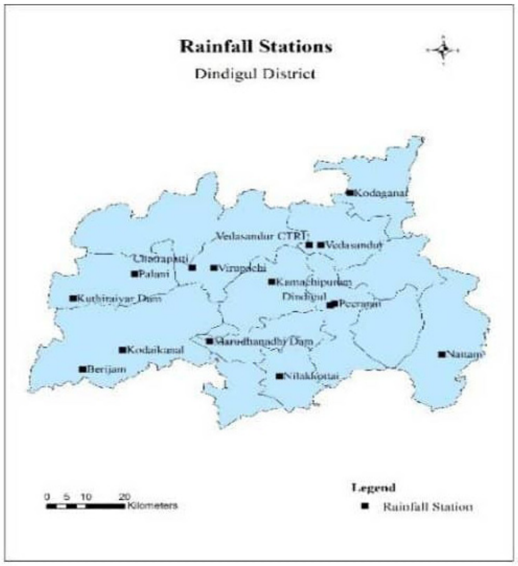

Figure 2: Location of Rainfall Stations

Table 1: Details of Rainfall Stations

Rainfall Stations	Latitude	Longitude	Elevation (in meters)
Vedasandur	10.531066	77.948121	212
Chatrapatti	10.468603	77.649948	136
Nilakkottai	10.165497	77.852450	226
Nattam	10.226478	78.229454	254
Palani	10.450684	77.516048	320
Dindigul	10.362660	77.969458	274
Kodaikanal	10.238674	77.4899095	2088
Berijam	10.185071	77.396134	2150
Kamachipuram	10.428219	77.833957	371
Vedasandur CTRI	10.53155	77.9209	217
Peeranai	10.367312	77.980288	194
Virupachi	10.466667	77.7	306
Marudhanadhi Dam	10.261944	77.69	327
Kodaganar	10.686388	77.969720	427
Kuthiraiyar Dam	10.381944	77.37333	385

■ Review of Literature

Previous studies in Rainfall and Temperature analysis:

Rainfall and temperature are the fundamental physical parameters as they determine the environmental conditions of a given region.[15] Increasing surface temperature leads to changes in rainfall,[16] and the analysis of temperature variations remains an important point of discussion.[17] The effects of climatic changes on rainfall and temperature have received much attention from researchers worldwide[18] and at the regional level.[19] Increased surface temperatures and rainfall variability can lead to crop failure and increased incidents of pests.[20] Analysis of long-term temperatures and precipitation trends is extremely important for rain-fed agricultural regions.[21]

Previous studies in Uniformity using Homogeneity Tests in Rainfall and Temperature analysis:

Rainfall records are critical to a climate-related study, and often changes in data collection methods, relocation of stations, and outdated equipment affect the data availability.[22] A data series is "homogenous" only if the recorded data are actually due to climatic variations[23] and not to non-climatic factors (i.e., measurement errors, instrument errors, or errors due to other human-induced changes).[23] The homogeneity of the time series was tested using the Standard Normal Homogeneity Test (SNHT),[24] and the Buishand's Range Test (BRT).[25] The results showed that all data sets in Bangladesh[26] were homogeneous. Three homogeneity tests, namely, SNHT, BRT, and Pettitt Test (PT), are used to examine the homogeneity of rainfall data.[27] The PT and SNHT developed by Alexandersson and Moberg are used to study the changes in annual and seasonal rainfall datasets for all meteorological subdivisions in India.[28] Buishand's Range Test (BRT), Pettitt's Test (PT), and Von Neumann's Ratio Test (VNRT) are used along the coastal districts of Maharashtra.[29] SNHT has been used to test the homogeneity of long-term data series at a 5% significance level in the northeastern states of India.[30]

Previous studies in Variability using the Box & Whisker Test and Coefficient of Variability in Rainfall and Temperature analysis:

Analysis of annual rainfall time series from 1980-2013 from many rain gauge stations was carried out using box and whisker plots in the semi-arid region of southern India.[27] Monthly, annual, and seasonal rainfall data were presented in box plots in the northeastern states of India.[30] Box and whisker plots were constructed for monthly rainfall in Kalahandi, Bolangir, and Koraput districts from 1980 to 2017.[31] The boxplots are analyzed for the monthly rainfall figures from 1975 to 2009 for the Brong Ahafo Region in Ghana.[32]

The coefficient of variation (CV) represents the ratio between the standard deviation and the mean and is used to differentiate the degree of variation from one data series to another.[33] A higher CV value indicates greater variability, and vice versa.[34] Analysis of spatiotemporal annual rainfall variability in the Wadi Cheliff Basin, Algeria, from 1970 to 2018 shows an opposite spatial pattern between CV and annual rainfall.[35] The CV for rainfall and rainy days is calculated for Ghataprabha River Basin, India.[36] The trend, variability, intensity, number of dry days, mean rainfall pattern, and variability in annual and SW monsoon seasons between 1989 to 2018 are analyzed, district-wise, for Kerala and West Bengal.[37]

Previous studies in Patterns using Cluster Dendrograms in Rainfall and Temperature analysis:

The cluster analysis of 27 rainfall stations was done using the agglomerative hierarchical clustering technique with the criteria of Ward's minimum variance method and Squared Euclidean Distance method using Statistica for southern India.[27]

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

The Mann-Kendall (MK), a nonparametric test, has been used consistently to detect an upward or downward trend in a range of hydrologic climate and environmental data.[38] The MK test can be used for any variable for trend detection.[39] The MK test was used to examine rainfall and temperature trends in the southern Gonder zone, Ethiopia.[40] The MK test was used to estimate the trend of more than 500 rain gauge stations over 50 years in Italy.[41] The trend of climatic variables between the years 1977 to 2012 in 4 rain gauge stations of Togo, Africa, was analyzed using the MK test.[42] A study of rainfall trends using the MK test between 1950 and 2015 was researched in the river catchment in the southwestern Ghats, India, for different seasons.[43] The Mann–Kendall's test was used to analyze the trend direction of rainfall in India's 12 semi-arid districts of western Rajasthan.[44]

Sen's estimator is a non-parametric method used for trend analysis and magnitude of the hydroclimate dataset.[45] Sen developed an innovative trend analysis for meteorological, hydrological, and environmental variables.[46] The trend analysis of temperature and its significance level in Gombe state, Nigeria, was studied using Sen's estimator.[47] MK and Sen's slope trend analysis are applied to investigate India's seasonal stream flow variability.[48] Similar studies are done for 21 stations from 1991-2020 in Mandya, Karnataka.[49], Kashmir Himalayas[50], and the northeastern states of India and Odisha.[30,31]

Previous studies in Prediction using ARIMA in Rainfall and Temperature analysis:

Prediction through providing statistics and facts about the future availability of rainfall is critical for managing water supply and demand, mitigating droughts, ensuring water levels in reservoirs, and devising mitigation measures.[51] Together with trend analysis, forecasting future changes in climate variables assists policy planners.[52] The Coastal Development Strategy prepared by the Water Resources Planning Organization predicts that monsoon rainfall in Bangladesh will increase by 12 % and winter rainfall will decrease by 10 % by 2100.[53] Research predicted that a temperature rise would exacerbate urban heat in Addis Ababa, Ethiopia.[54] The Indian Climate Change Assessment Network from 2010 to 2030 projected an all-around increase in greenhouse gases for the Indian subcontinent, where annual mean surface temperature is projected to increase by 1.7 to 2.0 °C by 2030, which will be felt at higher altitudes.[55]

Various techniques, such as Moving Average (MA), Auto Regressive (AR), Auto Regressive Moving Average (ARMA), and Integrated ARMA (ARIMA), are widely used forecasting methods for analyzing rainfall patterns in different time series.[56] The autoregressive method assumes that the past can predict the future based on the correlation between the future and the past.[21] The Auto-Regressive Integrated Moving Average (ARIMA) model is used to predict future rainfall trends for the mean rainfall in Bangladesh.[26] The ARIMA model is used to predict rainfall in the Sylhet region[57] and in the coastal region of the Bay of Bengal.[58]

Results and Discussion

Analysis of Uniformity using Homogeneity Test for Rainfall and Temperature data:

In the study area, the Uniformity of monthly rainfall and temperature was analyzed using the Homogeneity test, at 15 rainfall stations, for 39 years from 1981 to 2020. The results are presented in Table 2 and Table 3. The Standard Normal Homogeneity Test (SNHT) and Buishand Range Test (BRT) are used to test the homogeneity at a 5 % significance level in all the rainfall stations. The null hypothesis states that the annual rainfall values are independent, identically distributed, and homogeneous, while the alternative hypothesis states that the mean changes abruptly at an unknown time.[59] The null hypothesis (H0) is accepted if the estimated p-value is greater than the a-value at a 5% significance level: otherwise, it is rejected.[27]

The results of the homogeneity tests for the rainfall and temperature data are shown in Tables 2 and 3, respectively. The tables show that the results are grouped into two classes depending on whether the hypothesis for both the tests- the homogenous (that accepts the Null hypothesis) and Non-homogenous (that rejects the Null hypothesis). In the analysis of monthly rainfall (Table 2), the highest value (10.063) of SNHT is found in Berijam and Kodaikanal stations. These stations are Non-homogenous, while the remaining 12 stations are homogenous. The non-homogeneity is observed in all rainfall stations for monthly temperature analysis (Table 3), which proves that the availability of daily and hourly data could be more consistent.

Table 2: Homogeneity Test for Rainfall Data

Station	SNHT		BRT		
	T-Value	p-Value	Q-Value	p-value	Result
Berijam	10.063	0.0181	1.5991	0.03065	Non-Homogenous
Chatrapatti	4.9667	0.2927	1.0896	0.4557	Homogenous
Dindigul	4.9667	0.2959	1.0896	0.4617	Homogenous
Kamachipuram	4.9667	0.289	1.0896	0.4629	Homogenous
Kodaganar	4.9667	0.2903	1.0896	0.4618	Homogenous
Kodaikanal	10.063	0.0192	1.5991	0.0317	Non-Homogenous
Kuthiraiyar Dam	5.119	0.2714	1.0512	0.5215	Homogenous
Marudhanadhi Dam	5.119	0.2758	1.0512	0.5214	Homogenous
Nattam	8.1513	0.0584	1.4639	0.07695	Homogenous
Nilakkottai	8.1513	0.0571	1.4639	0.0791	Homogenous
Palani	5.119	0.274	1.0512	0.5173	Homogenous
Peeranai	4.9667	0.2915	1.0896	0.4603	Homogenous
Vedasandur (CTRI)	4.9667	0.2943	1.0896	0.4592	Homogenous
Vedasandur	4.9667	0.292	1.0896	0.4633	Homogenous
Virupachi	5.119	0.2722	1.0512	0.519	Homogenous

Table 3: Homogeneity Test for Temperature Data

Station	SNHT		BRT		
	T-Value	p-value	Q-Value	p-value	Result
Berijam	9.2981	0.03015	2.1263	0.000	Non-Homogenous
Chatrapatti	8.8949	0.03755	1.9762	0.000	Non-Homogenous
Dindigul	9.5101	0.02635	1.8613	0.003	Non-Homogenous
Kamachipuram	9.5101	0.02595	1.8613	0.003	Non-Homogenous
Kodaganar	9.5101	0.02505	1.8613	0.004	Non-Homogenous
Kodaikanal	9.2981	0.03025	2.1263	0.0002	Non-Homogenous
Kuthiraiyar Dam	8.8949	0.03795	1.9762	0.0009	Non-Homogenous
Marudhanadhi Dam	8.8949	0.0345	1.9762	0.0008	Non-Homogenous
Nattam	9.5646	0.0262	1.9089	0.0019	Non-Homogenous
Nilakkottai	9.5646	0.025	1.9089	0.0020	Non-Homogenous
Palani	8.8949	0.0366	1.9762	0.001	Non-Homogenous
Peeranai	9.5101	0.0262	1.8613	0.0036	Non-Homogenous
Vedasandur (CTRI)	9.5101	0.0249	1.8613	0.0035	Non-Homogenous
Vedasandur	9.5101	0.0253	1.8613	0.0031	Non-Homogenous
Virupachi	8.8949	0.0365	1.9762	0.0009	Non-Homogenous

Analysis of Variability using Box & Whisker Test and Coefficient of Variability for Rainfall and Temperature Data:

The variability of monthly rainfall and temperature data for 39 years from 1981 to 2020 is analyzed using the Box & Whisker test and the Coefficient of Variability in the study area.

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Box & Whisker Test:

The Box and Whisker test for monthly rainfall data is shown in Figure 3. Studies show that the short boxes have less temporal variation, and the rainfall stations with the long boxes represent a highly dispersed and consistent rainfall pattern.[27] Similar conditions prevail in this study, as shown in Figure 3. The median line divides the long and short boxes into upper and lower quartiles. In the study area, four rainfall stations, Berijam, Kodaikanal, Nattam, and Nilakottai, have long boxes, while the remaining 11 stations have short boxes. In the case of Chatrapatti, Dindigul, Kamachipuram, Kodaganar, Peeranai, Vedasandur (CTRI), and Vedasandur rainfall stations, the median line within the boxes is in the upper quartile, which means that these stations have received less rainfall.

The Box and Whisker test for the monthly temperature data is shown in Figure 4. It shows that the long boxes with a highly dispersed temperature variation are found in the Berijam and Kodaikanal rainfall stations. In Palani, Virupachi, and Chatrapatti rainfall stations, the median line is in the lower quartile, exhibiting that these stations have experienced substantial temperature variation.

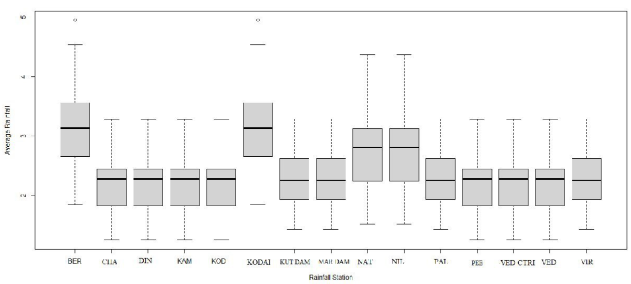

Figure 3: Box & Whisker Test for Rainfall Data

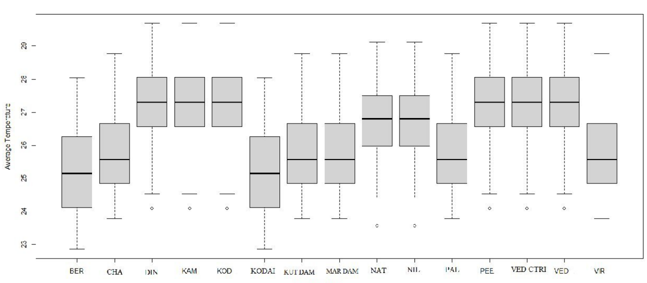

Figure 4: Box & Whisker Test for Temperature Data

Coefficient of Variability (CV):

This study calculated monthly rainfall and temperature variability using the Coefficient of Variability (CV), for 39 years, from 1981 to 2020. CV is calculated to examine the rainfall and temperature variability, and a higher value of CV is an indicator of greater variability, and vice versa, which is calculated as CV= σ/μ x 100, where σ is the standard deviation, and μ is the mean precipitation.[60]

The CV was calculated for the monthly rainfall and temperature data in the study area and is shown in Table 4 and Table 5, respectively. The coefficient of variability for the monthly rainfall data (Table 4) indicates that the Dindigul rainfall station has experienced the higher and Berijam and Kodaikanal have the lowest variability. The highest rainfall variability is noticed during February, followed by January and March, and the lowest variability is observed in October. The coefficient of variability for monthly temperature data (Table 5) reveals that Berijam & Kodaikanal rainfall stations have higher variability, and Dindigul, Kamachipuram, Kodaganar, Peeranai, Vedasandur CTRI, and Vedasandur rainfall stations, the lowest variability. The highest temperature variability is in October and November, and the lowest is in April.

Table 4: Coefficient of Variability analysis for Rainfall data

Station	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Berijam	167	153	122	70	59	61	44	37	57	46	49	93	22
Chatrapatti	165	187	158	98	64	73	65	51	54	46	60	94	21
Dindigul	99	123	129	140	109	121	147	138	94	100	122	101	96
Kamachipuram	165	187	158	98	64	73	65	51	54	46	60	94	21
Kodaganar	165	187	158	98	64	73	65	51	54	46	60	94	21
Kodaikanal	167	153	122	70	59	61	44	37	57	46	49	93	22
Kuthiraiyar Dam	174	160	131	78	57	51	43	36	52	45	52	96	20
Marudhanadhi Dam	174	160	131	78	57	51	43	36	52	45	52	96	20
Nattam	159	175	140	87	62	77	60	47	57	46	58	93	23
Nilakkottai	159	175	140	87	62	77	60	47	57	46	58	93	23
Palani	174	160	131	78	57	51	43	36	52	45	52	96	20
Peeranai	165	187	158	98	64	73	65	51	54	46	60	94	21
Vedasandur (CTRI)	165	187	158	98	64	73	65	51	54	46	60	94	21
Vedasantur	165	187	158	98	64	73	65	51	54	46	60	94	21
Virupachi	174	160	131	78	57	51	43	36	52	45	52	96	20

Table 5: Coefficient of Variability analysis for Temperature data

Station	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Berijam	10.02	10.74	7.54	6.77	7.37	12.17	13.47	11.38	12.82	15.03	13.17	12.37	5.16
Chatrapatti	8.95	9.10	7.45	5.96	6.32	11.90	12.16	8.62	11.44	11.48	13.80	12.80	4.82
Dindigul	9.14	8.53	7.80	6.95	6.58	8.30	9.70	6.22	8.76	12.48	15.41	13.01	4.76
Kamachipuram	9.14	8.53	7.80	6.95	6.58	8.30	9.70	6.22	8.76	12.48	15.41	13.01	4.76
Kodaganar	9.14	8.53	7.80	6.95	6.58	8.30	9.70	6.22	8.76	12.48	15.41	13.01	4.76
Kodaikanal	10.02	10.74	7.54	6.77	7.37	12.17	13.47	11.38	12.82	15.03	13.17	12.37	5.16
Kuthiraiyar Dam	8.95	9.10	7.45	5.96	6.32	11.90	12.16	8.62	11.44	11.48	13.80	12.80	4.82
Marudhanadhi Dam	8.95	9.10	7.45	5.96	6.32	11.90	12.16	8.62	11.44	11.48	13.80	12.80	4.82
Nattam	9.36	9.79	8.05	7.07	7.86	8.36	10.84	7.57	10.92	15.15	16.50	14.18	4.81
Nilakkottai	9.36	9.79	8.05	7.07	7.86	8.36	10.84	7.57	10.92	15.15	16.50	14.18	4.81
Palani	8.95	9.10	7.45	5.96	6.32	11.90	12.16	8.62	11.44	11.48	13.80	12.80	4.82
Peeranai	9.14	8.53	7.80	6.95	6.58	8.30	9.70	6.22	8.76	12.48	15.41	13.01	4.76
Vedasandur (CTRI)	9.14	8.53	7.80	6.95	6.58	8.30	9.70	6.22	8.76	12.48	15.41	13.01	4.76
Vedasandur	9.14	8.53	7.80	6.95	6.58	8.30	9.70	6.22	8.76	12.48	15.41	13.01	4.76
Virupachi	8.95	9.10	7.45	5.96	6.32	11.90	12.16	8.62	11.44	11.48	13.80	12.80	4.82

Analysis of Spatial Patterns using Cluster Analysis for Rainfall and Temperature data:

The spatial pattern of monthly rainfall and temperature data, for 39 years, from 1981 to 2020, for the study area is analyzed using Cluster Dendrogram analysis. They are shown in Figure 5 and Figure 6, respectively. Cluster analysis was developed to classify a multivariate data set into homogeneous clusters with minimum dissimilarity within clusters and maximum contrast between clusters.[61] In this study, the R programming software K Means Clustering technique is used to process the data.

The Cluster Dendrogram for monthly rainfall data (Figure 5) reveals the following conclusions. The trails were made by classifying the study area with four rainfall clusters where Cluster 1 consists of Berijam, Kodaikanal: Cluster 2 is found in Nattam, Nilakottai: Cluster 3 includes Kuthiraiyar Dam, Maruthanadhi Dam, Palani, Virupachi and the remaining taluks are classified under Cluster 4. In Kodaikanal and Berijam, classified as cluster 1, the rainfall is highly dispersed, indicating a higher distributed rainfall pattern as these two rainfall stations are located nearly 2088 and 2150 meters above the mean sea level, respectively. The Cluster Dendrogram for monthly temperature analysis (Figure 6) shows that there are four temperature clusters, Cluster 1 includes Berijam and Kodaikanal, Cluster 2 consists of Nattam, Nilakottai, Cluster 3 has Kuthiraiyar Dam, Maruthanadhi Dam, Palani, fall under cluster 4. The Cluster wise fluctuations in monthly rainfall and temperature in each cluster are oscillatory and do not have a regular pattern, as each cluster has specific rainfall and temperature aspects in the study area.

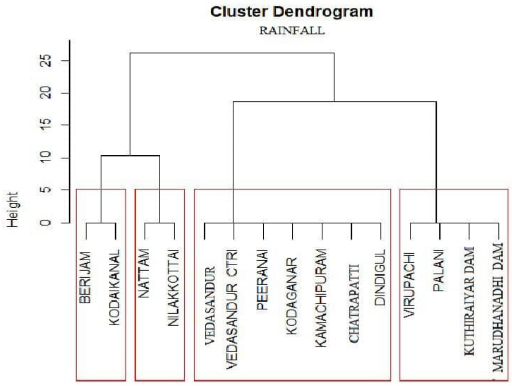

Figure 5: Cluster Dendrogram analysis for Rainfall data

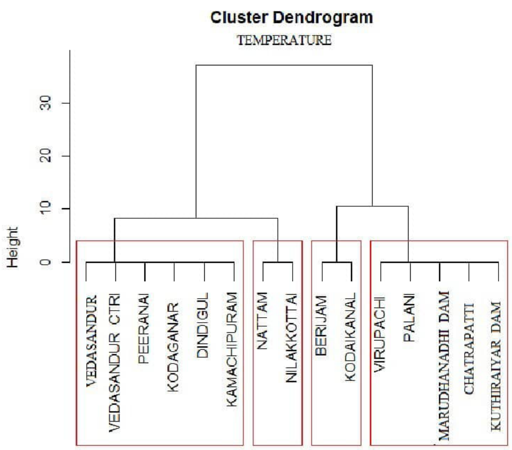

Figure 6: Cluster Dendrogram analysis for Temperature data

Trend analysis using Mann-Kendall and Sen's Slope for Rainfall and Temperature data:

Monthly rainfall and temperature trends are analyzed in the study area from 1981 to 2020 for 15 rainfall stations, using Mann-Kendall and Sen's slope tests. Tables 6 and 7 show the monthly rainfall and temperature patterns obtained in the study area using the Mann-Kendall test and Sen slope estimator, respectively. When performing the Mann-Kendall test, Kendall Tau, a measure of the correlation between two variables, is obtained, and the Kendall Tau takes values between ± 1.[62]

The following conclusions can be drawn from Table 6. The results based on the intensity of the z- value of the Mann-Kendall test at the significance level of 0.05 indicate that the monthly rainfall in January, March, June, July, September, and December shows a negative trend (-0.15 to -1.11). The z- value shows a positive trend, varying from 0.38 to 1.78, and observed in February, April, May, August, October, and November, with a strong positive trend (z- value 1.78) in May. Sen slope test shows an increasing trend (0.0051 to 0.0500) in February, April, May, August, October, and November and a decreasing trend, -0.0018 and -0.0486, in December, September, July, March, January, and June. The annual rainfall trend is increasing as both Sen's slope estimator and Kendall's tau (Z) are positive and found to be 0.00003 and 0.00002, respectively. The results of the Rainfall trend have shown an increase with notable trends perceived at the 95% confidence levels, as recommended.[63]

From Table 7, the following conclusions are drawn. The results based on the intensity of the z value of the Mann-Kendall test at the 0.05 significance level indicate that the monthly temperature has a negative trend (-0.18 to -2.06) in February, January, March, April, May, June, November, and December. The z value shows a positive trend, varying between 0.34 and 1.37, observed in July, August, September, and October, with a high positive trend (z value 1.37) found during August. Sen's slope test reveals an increasing trend (0.0054 to 0.0244) during September, August, July, and October and a decreasing trend, -0.0065 and -0.0363, February, January, April, May, June, November, December, and March. The trend of annual rainfall is increasing as both the slope estimator of the Sen and the tau (Z) values of Kendall are Negative and found to be -0.0406 and -0.2208, respectively. The results of the Rainfall trend have shown a decrease, with significant trends observed at the 95% confidence levels.

Table 6: Trend analysis for Rainfall data

Months	Z Score	Var S	Mann-Kendall Tau	P-value	Sen's Slope
Jan	-0.86235	7363.67	-0.0963	0.3885	-0.0033
Feb	0.71171	7346.00	0.0802	0.4766	0.0005
March	-0.39616	7365.67	-0.0449	0.692	-0.0023
April	0.38454	7364.67	0.0436	0.7006	0.0051
May	1.7826	7366.67	0.1974	0.0747	0.0276
June	-2.7613	7366.67	-0.3051	0.00[58]	-0.0486
July	-1.1186	7365.67	-0.1244	0.2633	-0.0229
Aug	1.4681	7365.67	0.1629	0.1421	0.0225
Sep	-1.1302	7366.67	-0.1256	0.2584	-0.0311
Oct	1.3632	7366.67	0.1513	0.1728	0.0488
Nov	1.503	7366.67	0.1667	0.1328	0.0500
Dec	-0.1515	7366.67	-0.0179	0.8796	-0.0018
Annual	0	7366.67	0.00002	1	0.00003

Table 7: Trend analysis for Temperature data

Months	Z Score	Var S	Mann Kendall Tau	P-value	Sen's Slope
Jan	-0.83916	7361.67	-0.0939	0.4014	-0.0168
Feb	-0.18643	7365.67	-0.0218	0.8521	-0.0065
March	-1.8292	7366.67	-0.2026	0.06737	-0.0363
April	-2.0628	7362.67	-0.2288	0.03913	-0.03349
May	-0.6641	7366.67	-0.0744	0.5066	-0.0086
June	-0.4311	7366.67	-0.0487	0.6664	-0.0081
July	1.0369	7366.67	0.1154	0.2998	0.0186
Aug	1.3749	7365.67	0.1527	0.1692	0.0185
Sep	0.3496	7365.67	0.0398	0.7267	0.0054
Oct	1.0604	7364.67	0.1181	0.289	0.0244
Nov	-1.6428	7366.67	-0.1820	0.1004	-0.0299
Dec	-1.27	7366.67	-0.1410	0.2041	-0.04
Annual	-1.9926	7364.67	-0.2208	0.0463	-0.0406

Prediction analysis using ARIMA Model for Rainfall and Temperature data:

The prediction analysis for rainfall and temperature is done in the study area from 1981 to 2020 for 15 stations, using the ARIMA model that applies the data in the past to prepare forecasts. The data was analyzed with R statistical R program software.

Box Jenkins Algorithm:

The Box Jenkins (1970)[64,65] advanced the ARIMA model. This method uses ARIMA time series models to systematically Identify, Estimate, and Check (goodness of fit)

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procedures.[66] 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.[67] 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 series[68] and used to initiate forecasts. This approach is typically useful for short to medium-term forecasting.[69] A set of data obtained sequentially over time is called a Time series. Box Jenkins formula is applied to generate a pattern and structure of the time series data collected and examine the best-fit model and forecast. This process is indicated in Table 8.

Table 8: Box Jenkins Algorithm[64,70]

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.

Prediction analysis for Rainfall data:

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 monthly rainfall and temperature calculated from 1981 to 2020 is shown in Figures 7 and 8, respectively. From the figures, 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.

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.[70] and the ACF and PACF plots for rainfall and temperature in Tables 9 and 10.

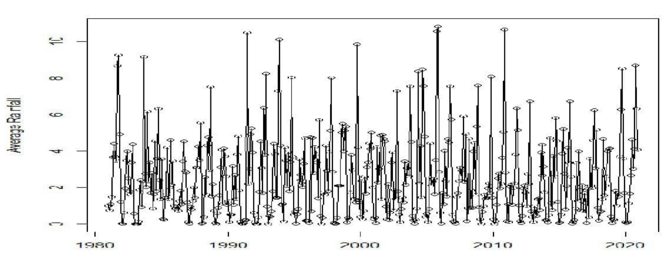

Figure 7: Time series plot for rainfall data

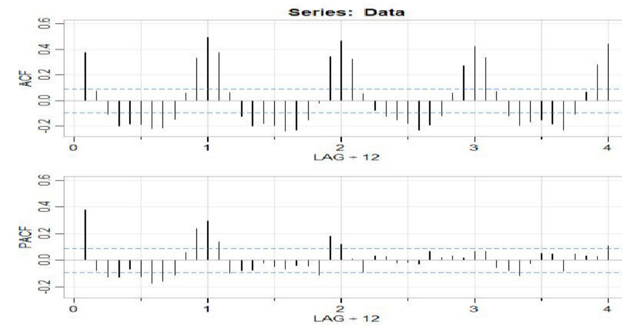

Figure 8: Time series plot for temperature data

Table 9: ACF and PACF plot for rainfall data

Lag	ACF	PACF	Lag	ACF	PACF	Lag	ACF	PACF	Lag	ACF	PACF
1	0.38	0.38	25	0.33	0.01	13	0.38	0.14	37	0.34	0.07
2	0.08	-0.08	26	0.06	-0.09	14	0.06	-0.10	38	0.07	-0.05
3	-0.11	-0.13	27	-0.08	0.03	15	-0.12	-0.08	39	-0.12	-0.08
4	-0.20	-0.13	28	-0.12	0.03	16	-0.20	-0.08	40	-0.19	-0.12
5	-0.18	-0.07	29	-0.15	-0.02	17	-0.18	-0.02	41	-0.17	-0.02
6	-0.19	-0.12	30	-0.18	-0.02	18	-0.19	-0.05	42	-0.15	0.05
7	-0.22	-0.17	31	-0.23	-0.03	19	-0.24	-0.07	43	-0.18	0.05
8	-0.21	-0.16	32	-0.19	0.06	20	-0.23	-0.04	44	-0.23	-0.08
9	-0.15	-0.11	33	-0.12	0.02	21	-0.15	-0.04	45	-0.11	0.05
10	0.06	0.06	34	0.06	0.03	22	-0.02	-0.11	46	0.07	0.03
11	0.33	0.24	35	0.27	0.02	23	0.34	0.18	47	0.28	0.03
12	0.50	0.30	36	0.43	0.07	24	0.47	0.12	48	0.44	0.11

Table 10: ACF and PACF plot for temperature data

Lag	ACF	PACF	Lag	ACF	PACF	Lag	ACF	PACF	Lag	ACF	PACF
1	0.68	0.68	25	0.55	-0.10	13	0.56	-0.07	37	0.53	0.00
2	0.31	-0.27	26	0.26	-0.01	14	0.25	-0.14	38	0.24	-0.09
3	-0.05	-0.28	27	-0.05	-0.02	15	-0.08	-0.09	39	-0.09	-0.11
4	-0.34	-0.21	28	-0.30	-0.02	16	-0.33	-0.04	40	-0.34	-0.06
5	-0.47	-0.10	29	-0.43	0.00	17	-0.47	-0.06	41	-0.46	0.02
6	-0.50	-0.20	30	-0.48	0.03	18	-0.51	-0.04	42	-0.48	0.01
7	-0.49	-0.27	31	-0.45	0.07	19	-0.50	-0.09	43	-0.46	-0.03
8	-0.37	-0.12	32	-0.33	-0.01	20	-0.37	-0.06	44	-0.34	0.02
9	-0.09	0.12	33	-0.08	0.04	21	-0.12	-0.04	45	-0.07	0.07
10	0.25	0.20	34	0.22	-0.07	22	0.23	0.09	46	0.23	-0.04
11	0.56	0.25	35	0.51	0.02	23	0.57	0.19	47	0.54	0.13
12	0.71	0.22	36	0.66	0.12	24	0.70	0.11	48	0.67	0.06

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 Figures 9 and 10, respectively. From the figures, 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 and temperature from January 1981 to December 2020 with $d = 0$ and $D = 0$.

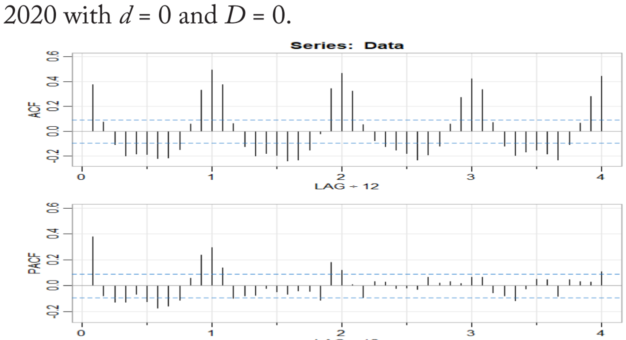

Figure 9: Time series ACF and PACF plot for rainfall data with Seasonal Differencing

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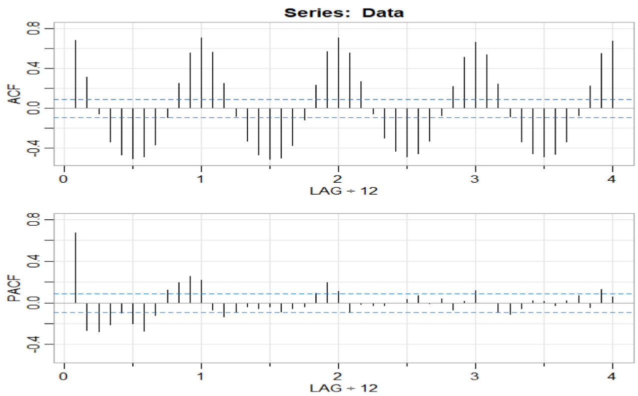

Figure 10: ACF and PACF plot for temperature data with Seasonal Differencing

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[71] and the same method is used in the present study. The ADF test will give a negative number on which the rejection of the hypothesis depends. This test uses two assumptions, the Null hypothesis, where the series is non-stationary, and the Alternative hypothesis, where the series is stationary.[72] 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,[72] and one can test the stationarity or time series data using the unit root test proposed by Dickey and Fuller in 1979.[73] The author[74,75,76] have used Dickey Fuller Test to forecast the rainfall pattern for the monthly weekly, and daily monsoon time series for 14 years. The same methodology is used in this research.

Rainfall
data: Data
Dickey-Fuller = -12.452, Lag order = 7, p-value = 0.01
alternative hypothesis: stationary
The test statistic: is -12.452, and the P-value: is 0.01
Since the p-value is less than .05, it could be inferred that the Monthly Rainfall data is Stationary.

Temperature
data: Data
Dickey-Fuller = -14.514, Lag order = 7, p-value = 0.01
alternative hypothesis: stationary
The test statistic: is -14.514, and the P-value: is 0.01
Since the p-value is less than .05, hence, conclude that Monthly Temperature data is Stationary.

Model Fit for Rainfall:

The 8 Identified ARIMA models were listed in Table 11 for monthly rainfall data. It could be observed that only ARIMA $(1,0,1)(1,0,1)_{12}$ has met the assumptions of the model diagnostics. The Best Model for the data is ARIMA (1,0,1) $(1,0,1)_{12}$ with an AIC score of 1855.23, as it has met the assumptions of the model diagnostics.

Table 11: ARIMA models for rainfall data

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

Model Fit for Temperature:

The 8 Identified ARIMA models were listed in Table 12., for monthly temperature data. It could be observed that only ARIMA $(1,0,1)(1,0,1)_{12}$ has met the assumptions of the model diagnostics. The Best Model for the data is ARIMA $(1,0,1)(1,0,1)_{12}$ with an AIC score of 1768.57, as it has met the assumptions of the model diagnostics.

Table 12: ARIMA models for temperature data

Model	AIC Value
(1,0,1) $(1,0,1)_{12}$	**1768.57**
(1,0,2) $(1,0,1)_{12}$	1770.34
(1,0,1) $(1,0,2)_{12}$	1770.53
(1,0,2) $(1,0,2)_{12}$	1772.29
(1,0,0) $(1,0,0)_{12}$	1941.11
(1,0,0) $(0,0,1)_{12}$	2017.60
(0,0,1) $(1,0,0)_{12}$	1965.66
(0,0,1) $(0,0,1)_{12}$	2065.40

Residual Plot:

The residual plots of monthly rainfall and temperature data are shown in Figures 11 and 12, respectively. The results shown in the figures are derived by following the method adopted by the author.[77] 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 figure that, in the Standardized Residuals, a sizeable positive residual is seen in 1992 and 1994 for monthly rainfall and 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.

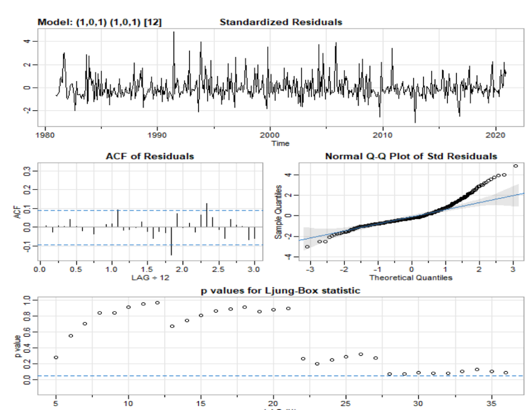

Figure 11: Residual plots for rainfall data

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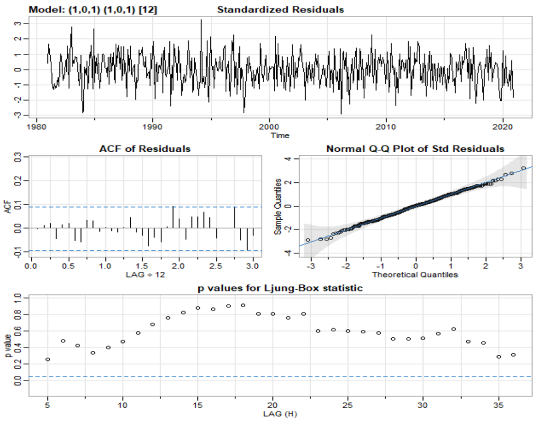

Figure 12: Residual plots for temperature data

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 by the author,[78] the model with the smallest AIC, and the same procedure is followed in the present research study. The study[79] also supports that the selection of the best-fit model is strongly associated with the best performance of the residual analysis.

Forecast for monthly Rainfall:

The ARIMA $(1,0,1)(1,0,1)_{12}$ with the minimum AIC (1855.23), the best model, is used to forecast the Monthly Rainfall for the next five years- 2021, 2022, 2023, 2024, and 2025. Figure 13 and Table 13 show the forecasted plots for monthly rainfall in the study area. The black line indicates the actual values and the red line depicts the predicted values. The monthly rainfall in the study area varies from about 700 mm to 1600 mm. It is maximum during the Northeast Monsoon Seasons- highest in October & November and gradually decreases in December. The rainfall distribution is found to be minimum in the northeast and progressively increases towards the South and Southwestern regions in the study area.

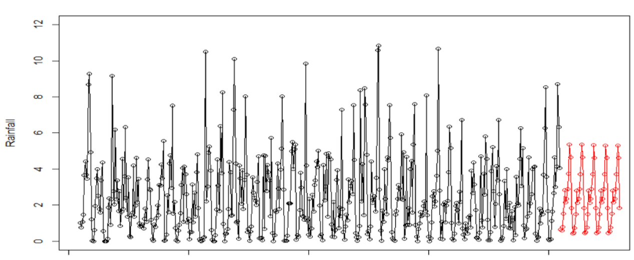

Figure 13: Forecast plots for monthly rainfall

Table 13: Forecast analysis for monthly rainfall

Month	2021	2022	2023	2024	2025
Jan	0.6545544	0.425139	0.4358805	0.4466577	0.4573767
Feb	0.6010922	0.4866647	0.4971189	0.5075653	0.5179553
March	0.791974	0.7361717	0.7453017	0.7544077	0.7634646
April	1.5253757	1.4966402	1.5016751	1.506696	1.5116898
May	2.8277935	2.8081616	2.8061194	2.804095	2.8020816
June	2.1407954	2.1332675	2.1348736	2.1364746	2.138067
July	2.3563189	2.3519925	2.352419	2.3528451	2.3532688
Aug	28.896896	28.84753	28.82303	28.798672	28.774445
Sep	37.260208	37.177482	37.107997	37.038892	36.97016
Oct	536.14982	534.50066	532.92696	531.36178	529.80506
Nov	465.41092	464.17577	462.9819	461.7945	460.6135
Dec	18.290816	18.321541	18.3539	18.386086	18.41181

Forecast for monthly temperature:

The ARIMA $(1,0,1)(1,0,1)_{12}$ with the minimum AIC (1768.57), the best model, is used to forecast the Monthly Temperature for the next five years- 2021, 2022, 2023, 2024, and 2025. Figure 14 and Table 14 show the forecasted plots for monthly temperature in the study area. The black line indicates the actual values and the red line depicts the predicted values. The average annual temperature in the study area is 21°C. It is maximum during April, followed by May and June.

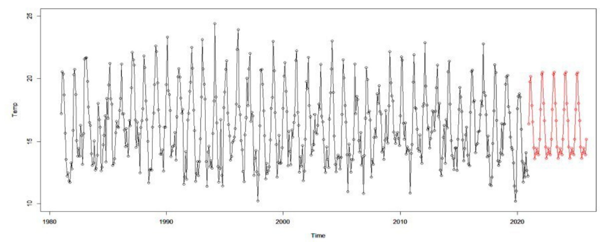

Figure 14: Forecast plots for monthly temperature

Table 14: Forecast analysis for monthly temperature

Month	2021	2022	2023	2024	2025
Jan	16.42864	17.52006	17.51992	17.51889	17.51787
Feb	19.75487	20.35547	20.35282	20.3498	20.34654
March	20.17596	20.50636	20.50337	20.5002	20.49687
April	37.83752	38.02051	38.01926	38.01786	38.01646
May	36.57904	36.68055	36.68023	36.67983	36.67943
June	34.49583	34.55334	34.55457	34.55575	34.55693
July	33.61528	33.64826	33.65015	33.652	33.65388
Aug	20.01704	20.03581	20.03739	20.03896	20.04053
Sep	14.45313	14.46389	14.46515	14.4664	14.46765
Oct	14.15611	14.16273	14.16421	14.16568	14.16715
Nov	13.93113	13.93568	13.93733	13.93897	13.94061
Dec	15.19346	15.19577	15.19648	15.19718	15.19789

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

A. The Centre for Environmental Information System (ENVIS), Tamil Nadu,[80] has taken steps to combat climate change and those following.

1.Tamil Nadu State Climate Change Cell (TNSCCC)[80] 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. 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, 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[80]

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)[80]

This would help identify measures that promote development objectives while yielding co-benefits for addressing climate change effectively and outlines 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)[80] 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)[81] 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)[81] 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.[81]

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.[81]

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.[81]

6. The State focuses on developing Early Warning Systems and Risk Management to monitor climate shocks.[81]

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.[81]

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.[81]

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.[81]

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.[81]

Conclusion

In the present study, an attempt is made to analyze the trend and prediction of rainfall and temperature using statistical techniques like-Homogeneity test, Box and Whisker Plot test, Coefficient of Variability, Cluster Dendrogram, Mann-Kendall, Sen's slope, and ARIMA model in Dindigul district, Tamil Nadu, India. The rainfall and temperature data are collected from 15 rainfall stations spread across the district for 39 years, from 1981 to 2020. The present study has used techniques admired worldwide by scientists for providing high-precision results. The primary and essential requirement for the management and developmental planning of any region in recent times sectors is the exploration of the spatiotemporal distribution and changing patterns of climatic variables, their trends, and forecast. This study would be helpful to assist the policy and decision-makers establish strategies and priorities to combat the changes in rainfall and temperature patterns in the study area and their stress on global climatic change.

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