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An Analysis Of The Spatial And Temporal Trends Of Precipitation From 1991 To 2020 In The Coimbatore District Of Tamil Nadu

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ABSTRACT

In this study, an investigation has been made to study the spatial and temporal variability of precipitation at Coimbatore districts of Tamil Nadu. India over 30 years (1991-2020) on an annual and seasonal basis. Mann-Kendal and Sen's slope estimator tests were used to detect change over time on an annual and seasonal basis. The cumulative deviations and Pettit-Mann-Whitney test were applied to detect possible change points. To explore the spatial distribution of trends, each station was interpolated using ArcGIS 10.5 on a seasonal and annual basis. The highest average rainfall, continuously surpassing 1500 mm, was recorded in Cincona Valparai, Sholayar, Valparai Pap, and Valparai Taluk Office between 1991 and 2000. Additionally, the yearly rainfall trend decreased from 2011 to 2020. At 1303.89 mm, Mettupalayam continuously recorded the highest average annual rainfall despite this trend. With an average rainfall of over 1260 mm, Periyanaiken Palayam and TN-Agri came in close second and third. Despite an increase in recent decades in some areas, such as Pollachi, temporal analysis shows a drop in rainfall over the past few decades, especially during the monsoon and post-monsoon seasons over the entire Coimbatore district in 30 years. This study highlights the need for adaptive strategies in water management and infrastructure development to mitigate the impacts of changing precipitation patterns in the Coimbatore district. Understanding these trends will support better planning for agricultural productivity, water resource management, and environmental sustainability.

Keywords: *Long-term Precipitation, Rainfall Patterns, Temporal Variability, Spatial Distribution, Climate Change, Water Resources*

1. INTRODUCTION

Precipitation is the most important climatic variable because it is the primary determinant in the choice of crops and ecological change in the type of food grains. Its fluctuation has a major impact on how food grains are distributed geographically. Significant temporal and regional variability in precipitation was noted by the IPCC (2007) throughout Asia. According to studies, areas of Pakistan's arid plains (**Farooq and Khan, 2004**), Northeast and North China (**Hu *et al.*, 2003),** and Russia (**Peterson *et al.*, 2002**) have seen decreasing annual rainfall, while Western and southeastern China (**Shi *et al.*, 2002; Hu *et al.*, 2003**), Bangladesh (**Mirza, 2002**), and the Philippines (**Cruz *et al.*, 2006**) have seen increases. According to various studies, the annual mean precipitation has been declining in parts of Russia (**Peterson *et al.*, 2002; Savelieva *et al.*, 2000**), Pakistan's arid plains (**Farooq and Khan, 2004**), and Northeast and North China (**Hu *et al.*, 2003; Zhai and Pan, 2003**). Precipitation patterns have been increasing over the western shores of Bangladesh (**Mirza, 2002**), the Philippines (**Cruz *et al.*, 2006**), southern China (**Hu *et al.*, 2003**), and Western China (**Shi *et al.*, 2002**).

In India, long-term studies have shown that rainfall patterns vary by location, from rising to dropping. (**Rupa Kumar *et al.*, 1992**) observed growing patterns along the west coast and northwest India and dropping patterns in Uttar Pradesh, Gujarat, Kerala, and eastern Madhya Pradesh between 1871 and 1984. According to (**Guhathakurta and Rajeevan., 2007**), between 1901 and 2003, monsoon rainfall fluctuated considerably among several meteorological subdivisions. There were significant declines in certain areas and increases in others. The yearly precipitation in the major Indian areas did not, however, show any apparent change between 1901 and 2000, according to (**Joshi and Pandey., 2011**).

These trends are investigated using a variety of statistical methods, and non-parametric tests like the Mann–Kendall (MK) test are often used due to their ability to withstand outliers and non-normal data distributions. The MK test does not involve data modification and performs well with missing or censored data (**Helsel, 1987**). However, serial correlation within time series data may increase the amount of false-positive results and impact the accuracy of the MK test. To address this, researchers have suggested prewhitening techniques (**Von Storch, 1995**) and updated MK test versions (**Hamed and Rao, 1998**). Although prewhitening can help remove serial correlation, it may also weaken trend signals if applied carelessly (**Yue and Wang, 2002**).

The Indian economy is based on agriculture, which employs over 70% of the labor force in certain states. Additionally, (**Darshana Duhan *et al*., 2013**) state that it is highly susceptible to variations in rainfall. Previous studies that have looked at rainfall trends have primarily focused on large-scale meteorological subdivisions. Nevertheless, there is an increasing need for district-level research that offers more precise data for regional planning of agricultural and water resources. The primary objective of the current study is to examine long-term rainfall trends and patterns in the Coimbatore district from 1991 to 2020. It aims to assess variations in rainfall across time and space and look into how they impact the environment, water resources, and agriculture. By providing a more localized understanding of precipitation dynamics, this work seeks to facilitate better planning and adaptation strategies in light of climatic variability.

2. MATERIALS AND METHODS

2.1. Study area

Coimbatore district, known as the "Manchester of South India," covers an area of 4,723 km², accounting for 5.74% of Tamil Nadu's area. It is the second most urbanized district in the state after Chennai. Located between 11° 0′ 45″ N and 76° 58′ 17.04″ E, Coimbatore is bordered by Tiruppur, Nilgiris, and Erode districts in Tamil Nadu and Palakkad, Idukki, Thrissur, and Ernakulam districts of Kerala. The district is divided into three revenue blocks — Coimbatore North, Coimbatore South, and Pollachi — and includes eleven taluks: Annur, Anaimalai, Coimbatore North, Coimbatore South, Kinathukkadavu, Madukkarai, Mettupalayam, Perur, Pollachi, Sulur, and Valparai.

The district of Coimbatore is renowned for its varied ecosystems, abundant agricultural output, and reliance on rainfall for irrigation. It experiences monsoon rains from June to September and has a tropical climate that is both dry and rainy. The region's geography consists of hill ranges and undulating uplands, and its geology comprises Archean gneissic and granitic rocks. Red calcareous soils are among the major soil types that support farming. The slope from the Western Ghats helps the district's drainage system, while the Noyal River and related tanks are essential for water management.

Coimbatore's temperature ranges from 35°C in the summer to 18°C in the winter. The district receives an average annual rainfall of 700 mm, mainly from the northeast (47%) and southwest (28%) monsoons. Major rivers include Bhavani, Noyyal, Amaravathi, Kousika, Bharathapuzha, and Aliyar. The Siruvani Dam is the primary drinking water source, famous for its sweet water. Notable waterfalls are Chinnakallar, Monkey Falls, Sengupathi, Siruvani, Thirumoorthy, and Vaideki Falls.

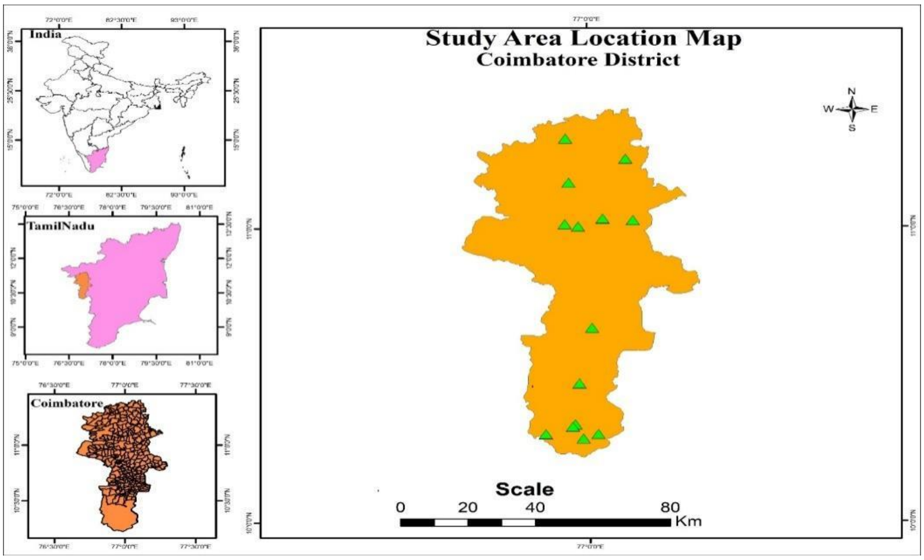
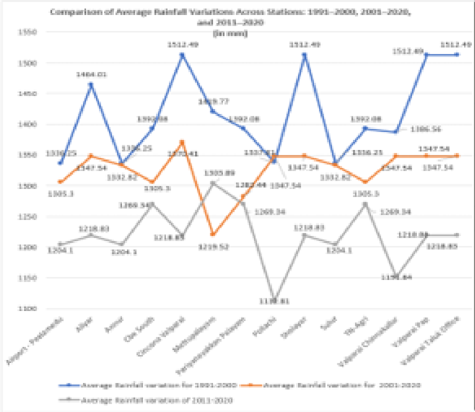


Figure No.1 Location of metrological stations of Coimbatore District.

2.2. Details of data

Monthly precipitation data of 14 stations covering a period of 30 years (1991–2020) were downloaded from Indian Meteorological Department (IMD) site India water portal (http://www.indiawaterportal.org/metdata) and location of meteorological stations with annual mean precipitation (long term average 1991–2020) is presented in Fig. 1. Data quality control is a necessary step; however, since MK and Pettit tests are non-parametric rank-based tests, they are robust against outliers. For the present study, the data series were plotted to detect the outliers. After visual detection of outliers, the suspected values were calculated using the normal ratio method.

The results shown in **Table 1** indicate that average decadienal rainfall variance during the period 1991–2000, Cincona Valparai, Sholayar, Valparai Pap, and Valparai Taluk Office recorded the highest average rainfall, consistently exceeding 1500 mm.



Station	1991-2000	2001-2010	2011-2020
Airport - Peelamedu	1336.25	1305.3	1204.1
Aliyar	1464.01	1347.54	1218.83
Annur	1336.25	1332.82	1204.1
Cbe South	1392.08	1305.3	1269.34
Cincona Valparai	1512.49	1370.41	1218.83
Mettupalayam	1419.77	1219.52	1303.89
Periyanayakkan Palayam	1392.08	1282.44	1269.34
Pollachi	1337.81	1347.54	1112.81
Sholayar	1512.49	1347.54	1218.83
Sulur	1336.25	1332.82	1204.1
TN-Agri	1392.08	1305.3	1269.34
Valparai Chinnakallar	1386.56	1347.54	1151.84
Valparai Pap	1512.49	1347.54	1218.83
Valparai Taluk Office	1512.49	1347.54	1218.83

Table.1 & Figure No.2 Comparison of Average Rainfall Variations Across Stations: 1991–2000, 2001–2020, and 2011–2020 (in mm)

2.3. Methodology

The methodology following the sequence for the analyses; namely, (1) the preliminary analysis of statistical parameters (mean, standard deviation, and coefficient of variation) of annual precipitation series was computed for each station for 1991 to 2020,(2) series are checked for general patterns in the data over time by MK test and Sen Slope estimator test (Sen, 1968) are applied to the whole time series to detect the direction and magnitude of a trend, (3) Mann–Whitney-Pettitt (PWM) test (Pettitt, 1979), (4) MK is applied again on the subseries identified by MWM test, comparing the averages annual precipitation for the whole series and the most recent subseries identified by MWM test is used for spatial analysis using ArcGIS 10.5.

2.3.1. Spatial analysis of precipitation series:

To explore the spatial distribution of trends on annual and seasonal basis was interpolated using ArcGIS 10.5 based on each stations for entire study period (1991–2020) An inverse distance weighted interpolation method (IDW) which is based on the assumption that the interpolation surface should be influenced most by nearby points and less by more distant points (Gemmer et al., 2004) was used. A variable search radius with a minimum sample of 12 points was used. To control the significance of surrounding points on the interpolated value, the exponent of distance (power) four was used because the higher power results in less influence from distant points.

3. RESULTS AND DISCUSSION:

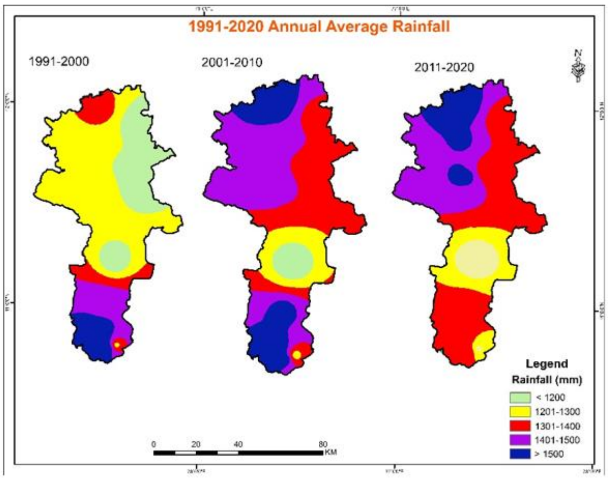


Figure No.3 Interpolation method for 30 years of annual average rainfall

The statistical parameters (mean, standard deviation, and coefficient of variation) of annual precipitation were computed for each station from 1991 to 2020. The map (Fig. 3) shows the annual average rainfall distribution in the Coimbatore district over three decades: 1991-2000, 2001-2010, and 2011-2020. Over time, high rainfall zones (1400-1600 mm) have shifted, with a reduction in areas receiving 1100-1300 mm rainfall, indicating changes in precipitation patterns due to climate change, deforestation, and urbanization.

Western and Northern Coimbatore receive more rainfall due to the Western Ghats, while the eastern parts, lying in the rain shadow region, receive less. Urbanization and land-use changes, especially in southern areas like Coimbatore city and industrial zones, have contributed to reduced rainfall through the urban heat island effect. The decline in higher rainfall areas (blue and purple zones) is due to reduced vegetation and water bodies.

Coimbatore receives rainfall from both the Southwest Monsoon (June- September) and Northeast Monsoon (October-December). The observed reduction in high rainfall zones highlights the need for water conservation, afforestation, and sustainable urban planning in the district.

3.1. Long-term pattern in decadienal seasonal precipitation:

The normalized seasonal (Fig.4) precipitation statistics (pre-monsoon, monsoon, post-monsoon, and winter) have a significant impact on water resources, agriculture, and the general climatic equilibrium of the Coimbatore district, as shown in Table 2. This study examines long-term climatic trends (climate signals) utilizing data from 14 major stations collected over three decades, 1991-2000, 2001-2010, and 2011-2020, to estimate seasonal fluctuations in average rainfall. The findings show considerable regional and temporal changes, providing useful insights into the shifting rainfall patterns over the last 30 years.

Winter Season		Pre-monsoon Season (Summer)			Southwest Monsoon Season				Post-monsoon Season (Autumn)		
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Figure No.4: India's Climate Calendar

	Pre-Monsoon			Monsoon			Post-Monsoon			Winter		
Stations	1991-2000	2001-2010	2011-2020	1991-2000	2001-2010	2011-2020	1991-2000	2001-2010	2011-2020	1991-2000	2001-2010	2011-2020
Airport -Peelamedu	69.32	100.35	78.93	244.84	207.84	224.74	137.73	140.08	99.56	1.49	6.86	5.25
Aliyar	2569.23	1971.69	2074.00	89.16	127.83	136.66	256.92	197.17	207.40	9.22	12.78	13.67
Annur	69.32	100.35	78.93	244.84	207.84	224.74	137.73	140.08	99.56	1.49	209.42	5.25
Cbe-south	73.20	103.67	84.39	259.47	219.95	237.35	136.33	131.90	102.96	2.01	6.43	5.88
Cincona Valparai	97.97	118.85	95.31	256.92	197.17	207.40	158.34	148.75	106.58	9.19	12.78	13.67
Metupalayam	75.20	107.83	86.94	269.11	227.51	249.69	132.07	132.22	98.50	2.74	7.15	4.81
Periyanaiken palayam	73.20	103.67	84.39	259.47	219.95	237.35	136.33	131.90	102.96	2.01	6.43	5.88
Pollachi	79.17	103.70	82.50	227.92	177.15	190.67	149.52	142.43	102.99	3.82	8.22	8.11
Sholayar	97.97	118.85	95.31	256.92	197.17	207.40	158.34	148.75	106.58	9.19	12.78	13.67
Sulur	126.04	182.45	78.93	445.16	377.88	332.58	250.42	254.70	99.56	0.93	9.74	5.25
Tn-Agri	73.20	103.67	84.39	259.48	219.95	237.35	136.33	131.90	102.96	2.01	6.43	5.17
Valparai Chinnakalar	88.83	113.18	88.83	230.49	191.76	230.49	461.63	181.93	643.56	6.91	9.55	16.45
Valparai Pap	114.64	205.00	114.64	256.92	136.91	256.92	158.34	446.25	158.34	58.90	471.82	58.90
Valparai Taluk /office	114.64	136.91	107.32	256.92	197.17	207.40	158.34	148.75	106.58	9.19	12.78	13.67

Table.2 : Seasonal Comparison of Average Rainfall Across Stations for 1991–2000, 2001–2010, and 2011–2020 (Pre-Monsoon, Monsoon, Post-Monsoon, and Winter)

Pre-Monsoon Rainfall (1991–2020):

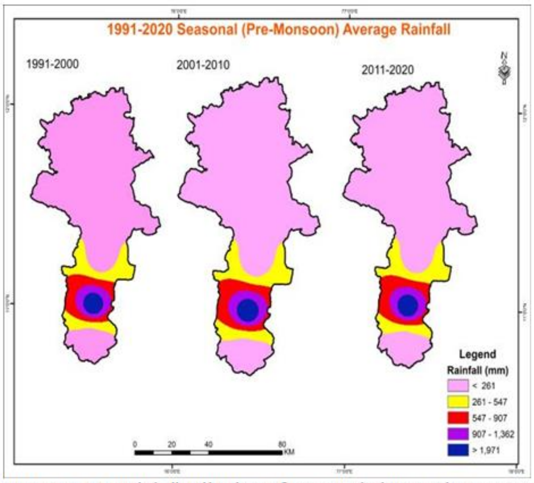


Figure No.5 Spatial distribution of temporal changes in pre monsoon during 1991-2020 for Average Rainfall

Pre-monsoon rainfall (Fig. 5) varied significantly across the Coimbatore district over three decades. Aliyar had the most rainfall, however, it decreased from 2569.23 mm (1991-2000) to 1971.69 mm (2001-2010), with a minor increase to 2074.00 mm (2011-2020). Valparai Chinnakalar and Valparai Pap also got considerable rainfall, however, Peelamedu, Annur, and Sulur reported significantly lower numbers, with Sulur dropping to 78.93 mm between 2011 and 2020. The Western Ghats influence increased rainfall in the south and southwest, whilst urbanization and land-use changes have contributed to lower rainfall in other areas.

Monsoon Rainfall (1991–2020):

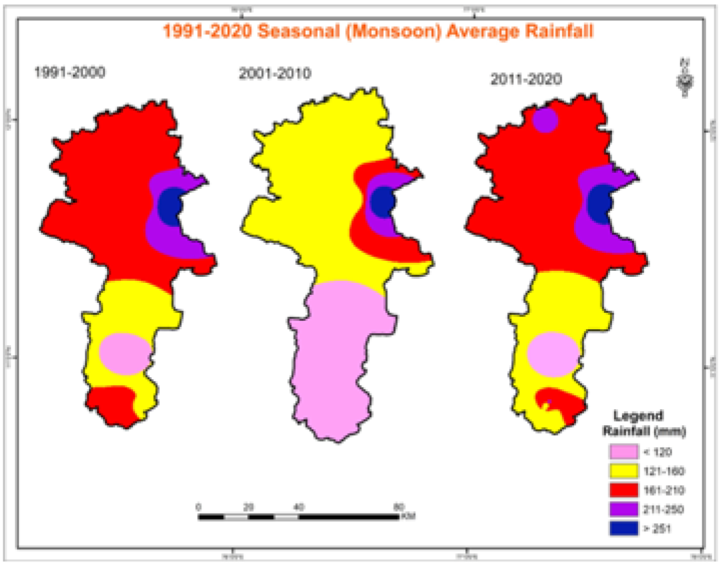


Figure No.6 Spatial distribution of temporal changes in monsoon during 1991-2020 for Average Rainfall

Monsoon rainfall remained the dominant season across Coimbatore (Fig. 6), with Sulur recording the highest rainfall, though declining from 445.16 mm (1991–2000) to 332.58 mm (2011–2020). Pollachi recorded the lowest rainfall, especially in 2001–2010 (177.15 mm). Mettupalayam showed a steady increase, reaching 249.69 mm in 2011–2020. Valparai Chinnakalar maintained stable rainfall above 230 mm. These variations reflect the impact of climate variability, deforestation, and urbanization on monsoon patterns, highlighting the need for adaptive strategies in agriculture and water management.

Post-Monsoon Rainfall (1991–2020):

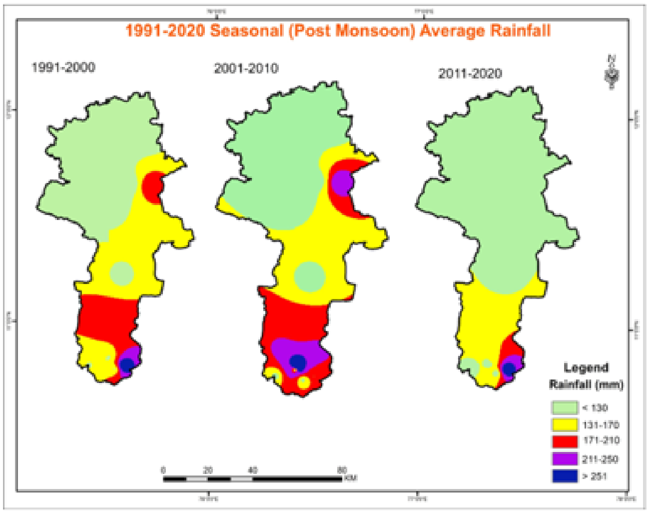


Figure No.7 Spatial distribution of temporal changes in post monsoon during 1991-2020 for Average Rainfall

Post-monsoon rainfall showed clear spatial variations across Coimbatore (Fig. 7). Valparai Chinnakalar recorded the highest rainfall in 1991–2000 (461.63 mm) and increased to 643.56 mm in 2011–2020, while stations like Peelamedu, Annur, and Sulur consistently recorded lower rainfall, with Sulur dropping to 99.56 mm in 2011–2020. Valparai Pap peaked at 446.25 mm in 2001–2010 but declined later. These variations highlight the need for effective water resource management and planning, particularly in regions like Valparai with high post-monsoon rainfall and low-rainfall zones like Sulur and Coimbatore South.

Winter Rainfall (1991–2020):

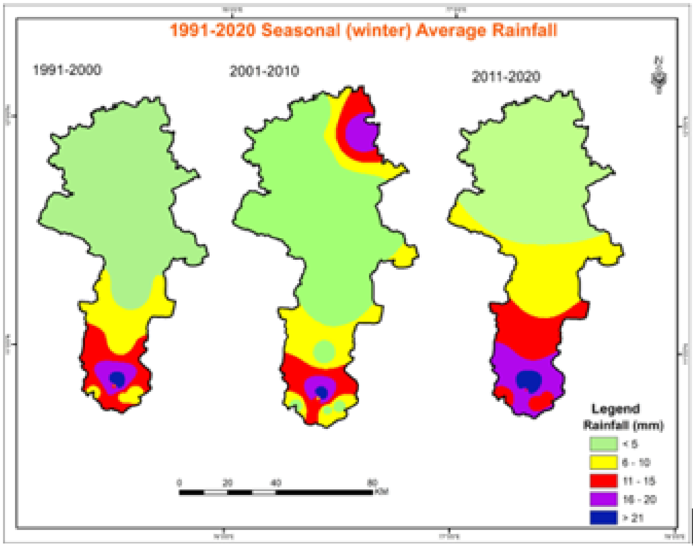


Figure No.8 Spatial distribution of temporal changes in Winter during 1991-2020 for Average Rainfall

Winter rainfall was generally low across Coimbatore, except in Valparai Pap, which recorded the highest rainfall of 471.82 mm during 2001–2010 (Fig.8). Other stations like Peelamedu, Sulur, and Pollachi received less than 10 mm of rainfall in 1991–2000 and 2011–2020. Valparai Chinnakalar showed a slight increase to 16.45 mm in 2011–2020. These variations highlight the significance of Valparai Pap in winter rainfall, which is essential for regional water availability, agriculture, and groundwater recharge during the dry season.

3.2 Station-Specific Insights and Seasonal Variations Across Decades

Aliyar recorded the highest pre-monsoon rainfall, while Sulur led in monsoon rainfall. Stations like Peelamedu, Annur, and Coimbatore South consistently recorded low rainfall, indicating vulnerability. Pollachi had moderate monsoon but low pre-monsoon and winter rainfall. Pre-monsoon rainfall declined at most stations except for a slight increase in Aliyar (2011–2020). Monsoon rainfall, though dominant, showed a declining trend, with Sulur leading but reducing over time. Post-monsoon rainfall increased in Valparai Chinnakalar (2011–2020), while winter rainfall remained low except for Valparai Pap (2001–2010).

3.3 Spatial Distribution Trends

Interpolated maps reveal that pre-monsoon rainfall was highest in Aliyar and Valparai, while Sulur and Mettupalayam recorded low values. Monsoon rainfall spread widely, concentrating around Sulur and Mettupalayam. Post-monsoon and winter rainfall were localized, with Valparai Chinnakalar and Valparai Pap receiving the most while southern Coimbatore remained relatively dry over the decades.

3.4 Implications for Water Resource Management

These rainfall trends call for targeted water management. High rainfall areas like Aliyar, Sulur, and Valparai should focus on rainwater harvesting, while low rainfall regions like Peelamedu, Annur, and Coimbatore South need efficient irrigation and sustainable water systems. Seasonal and decadal variations stress the need for adaptive strategies to manage changing rainfall patterns in Coimbatore.

3.5 Mann-Whitney Pettit Test of Seasonal Trends Across Stations:

The Mann-Whitney Pettit test (Table 3) assessed rainfall trend homogeneity from 1991 to 2020 across seasons. Airport-Peelamedu, Annur, Metupalayam, Sulur, and Periyanaiken Palayam showed stable rainfall ($p > 0.05$). Aliyar showed shifts in Monsoon ($p = 0.357$) and Winter ($p = 0.344$). Cinchona Valparai ($p = 0.358$) and Pollachi ($p = 0.387$) indicated Post-Monsoon shifts. Sholayar showed variations in Post-Monsoon ($p = 0.358$) and Winter ($p = 0.297$), while Valparai Chinnakalar showed a Winter shift ($p = 0.267$), indicating climatic variations.

Stations	Pre-Monsoon		Monsoon		Post-Monsoon		Winter	
	t-value	p-value	t-value	p-value	t-value	p-value	t-value	p-value
Airport -Peelamedu	-0.183	0.885	0.373	0.773	0.890	0.537	-0.539	0.685
Aliyar	0.708	0.608	-1.592	0.357	0.708	0.608	-1.667	0.344
Annur	-0.291	0.820	0.373	0.773	0.890	0.537	-1.469	0.381
Cbe-south	-0.225	0.859	0.389	0.764	1.361	0.403	-0.779	0.579
Cincona Valparai	0.060	0.962	0.708	0.608	1.589	0.358	-1.984	0.297
Metupalayam	-0.222	0.861	0.304	0.812	0.991	0.503	-0.307	0.811
Periyanaiken palayam	-0.225	0.859	0.389	0.764	1.361	0.403	-0.779	0.579
Pollachi	-0.067	0.958	0.357	0.782	1.438	0.387	-0.951	0.516
Sholayar	0.060	0.962	0.708	0.608	1.589	0.358	-1.984	0.297
Sulur	0.297	0.816	5.122	0.123	0.946	0.518	-0.325	0.800
Tn-Agri	-0.225	0.859	0.389	0.764	1.361	0.403	-0.556	0.677
Valparai Chinnakalar	0.000	1.000	0.000	1.000	-0.245	0.847	-2.239	0.267
Valparai Pap	0.000	1.000	0.000	1.000	0.000	1.000	0.000	1.000
Valparai Taluk office	0.141	0.911	0.714	0.605	1.589	0.358	-1.659	0.345

Table No.3 Statistical Analysis of Seasonal Trends across Stations

Cinchona Valparai showed a potential Post-Monsoon shift ($p = 0.358$), while Monsoon remained stable ($p = 0.608$). Annur and Metupalayam exhibited consistent rainfall patterns ($p > 0.05$). Pollachi indicated a Post-Monsoon shift ($p = 0.387$), while Sholayar showed variations in Post-Monsoon ($p = 0.358$) and Winter ($p = 0.297$). Sulur and Periyanaiken Palayam remained stable, while Valparai Chinnakalar suggested a potential Winter shift ($p = 0.267$), indicating climatic variation.

Overall, (Fig. 9,10) most stations showed stable seasonal rainfall ($p > 0.05$), except for Aliyar, Cinchona Valparai, Pollachi, and Sholayar, which exhibited potential shifts. These findings are crucial for water management, agriculture, and infrastructure planning, emphasizing the need for adaptive strategies. Understanding rainfall trend homogeneity supports decision-making in crop selection, water storage, and disaster preparedness. The Mann-Whitney Pettit test effectively detects climatic variations, highlighting the importance of targeted strategies to manage changing weather conditions.

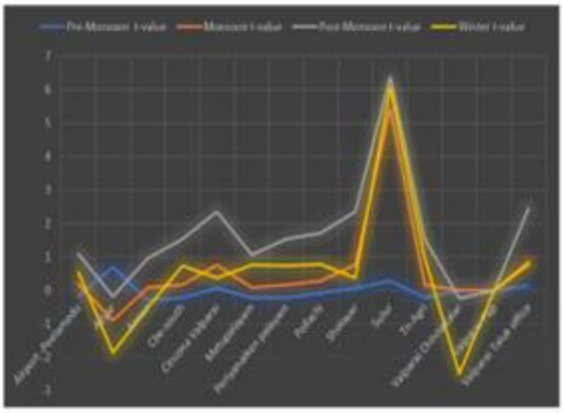


Figure No.9 t-Values of Seasonal Trends across Stations

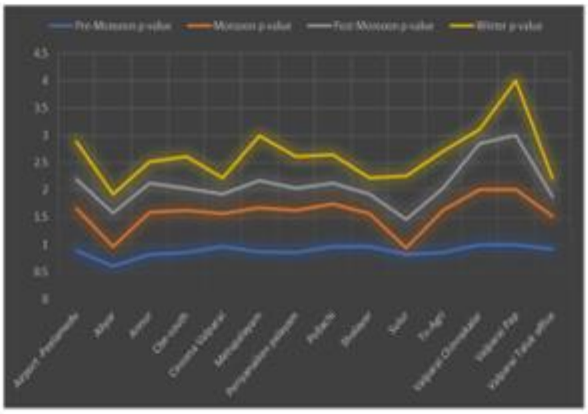


Figure No.10 p-Values of Seasonal Trends across Stations

3.6 Mann – Kendall Test - Annual Average rainfall data (1991-2020)

Stations	S	P-Value	S	P-Value	S	P-Value
Airport -Peelamedu	11	0.38	11	0.38	11	0.38
Aliyar	17	0.15	17	0.15	17	0.15
Annur	11	0.38	11	0.38	11	0.38
Cbe-south	3	0.86	17	0.16	17	0.16
Cincona Valparai	3	0.86	17	0.16	17	0.16
Metupalayam	5	0.73	25	**0.03**	5	0.73
Periyanaiken palayam	13	0.29	15	0.22	9	0.48
Pollachi	5	0.73	9	0.48	7	0.60
Sholayar	3	0.86	3	0.86	17	0.16
Sulur	11	0.38	11	0.38	11	0.38
Tn-Agri	13	0.29	15	0.22	9	0.48
Valparai Chinnakalar	3	0.86	17	0.16	17	0.16
Valparai Pap	3	0.86	17	0.16	17	0.16
Valparai Taluk /office	13	0.29	15	0.22	9	0.48

Table No 4 The Mann-Kendall test results of Annual Average rainfall data (1991-2020)

The Mann-Kendall (MK) test, a non-parametric method widely used in climatology and hydrology, is well-suited for detecting monotonic trends in time series data without the need for any distributional assumptions. Before applying the MK test, all data series were tested for Lag-1 autocorrelation (Anderson, 1941) at 1%, 5%, and 10% significance levels to eliminate the possible effects of serial correlation. The results confirmed that all series were serially independent (**Fu *et al*., 2009; Xu *et al*., 2007**), allowing the MK test to be applied directly to the original data without any pre-whitening procedures. Subsequently, the MK test was used to examine the annual average rainfall trends across stations for the period 1991–2020 (Table 4).

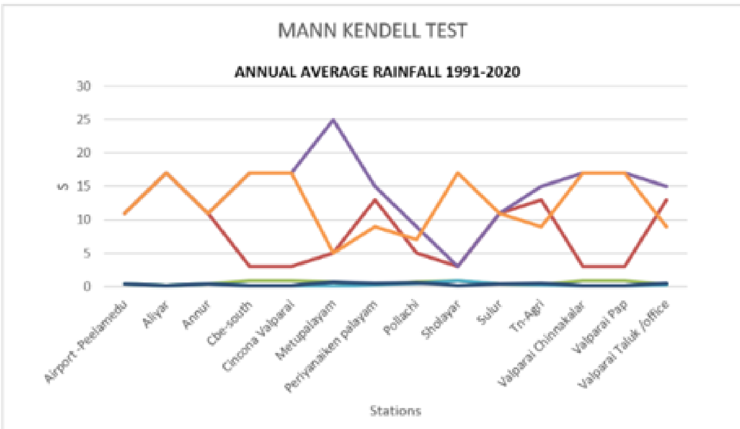


Figure No.11 Line graph for annual average rainfall using Mann Kendall Test

According to the Mann-Kendall test line graph (Fig. 11), the majority of stations — including Airport-Peelamedu, Annur, Sulur, Valparai, Aliyar, Cinchona Valparai, Sholayar, and TN-Agri — show no discernible rainfall patterns ($p > 0.05$), indicating consistent rainfall from 1991 to 2020. Similarly, no notable patterns were observed at other sites, such as Cbe-South, Periyanaiken Palayam, Pollachi, and Sholayar, further supporting the region's general rainfall stability. However, a noteworthy Winter trend ($p = 0.03$) was detected at Metupalayam, suggesting a possible seasonal shift in rainfall. Overall, the Mann-Kendall test results indicate stable rainfall trends across most stations during 1991–2020, except for Metupalayam, which shows a notable trend in the Winter season, reflecting consistent climatic conditions across the study area.

3.7 Sen's Slope

Sen's slope analysis (Table 5) of annual rainfall (1991–2020) indicates stable trends with near-zero values during 1991–2000 and 2001–2010. However, from 2011 to 2020, several stations exhibited higher positive trends, particularly Pollachi and TN-Agri, suggesting increased rainfall in recent years. Minimal rainfall changes were observed at Metupalayam, Aliyar, Annur, Cbe-South, Cincona Valparai, and Periyanaiken Palayam, with trends remaining close to zero. Pollachi showed a significant positive trend in 2001–2010 (0.81), which further increased in 2011–2020 (1.01), while Valparai Pap and Valparai Chinnakalar also recorded notable rainfall increases in the last decade. In contrast, Metupalayam exhibited a negative slope during 2011–2020, indicating a decline in rainfall. Overall, the recent decade reflects more pronounced rainfall variations, underscoring the need for localized studies to address climate change, land use changes, and environmental impacts.

Stations	1991-2000			2001-2010			2011-2020		
	95%			95%			95%		
	value	lower bound	upper bound	value	lower bound	upper bound	value	lower bound	upper bound
Airport -Peelamedu	0.10	-0.12	0.23	0.07	-0.09	0.22	0.11	-0.13	0.24
Aliyar	0.10	-0.05	0.23	0.10	-0.05	0.23	0.10	-0.05	0.23
Annur	0.01	-0.01	0.02	0.01	-0.01	0.02	0.01	-0.01	0.02
Cbe-south	0.12	-0.09	0.32	0.10	-0.09	0.21	0.08	-0.17	0.25
Cincona Valparai	0.09	-0.18	0.20	0.10	-0.05	0.23	0.16	-0.06	0.44
Metupalayam	0.16	-0.06	0.44	0.07	0.00	0.16	0.00	-0.11	0.12
Periyanaiken palayam	0.12	-0.09	0.32	0.10	-0.09	0.21	0.08	-0.17	0.25
Pollachi	0.02	-0.02	0.02	0.81	-1.39	2.50	1.01	-2.06	2.65
Sholayar	0.09	-0.18	0.20	0.06	-0.04	0.18	0.16	-0.06	0.44
Sulur	0.11	-0.13	0.24	0.07	-0.09	0.22	0.10	-0.12	0.23
Tn-Agri	0.01	-0.01	0.03	1.34	-1.16	2.75	1.03	-2.14	3.20
Valparai Chinnakalar	-0.05	-0.27	0.27	0.12	-0.06	0.30	0.10	-0.17	0.28
Valparai Pap	1.03	-2.14	3.20	0.10	-0.05	0.23	0.16	-0.06	0.44
Valparai Taluk /office	0.12	-0.09	0.32	0.10	-0.09	0.21	0.08	-0.17	0.25

Table No. 5 Sen's Slope data for 1991-2020

4. DISCUSSION

This study analyzes the variability and trends of annual and seasonal rainfall across fourteen stations in the Coimbatore district, Tamil Nadu, from 1991 to 2020. The results reveal clear spatial and temporal variations, reflecting broader climatic patterns in South India (**Krishnakumar *et al.*, 2009; Ramesh & Goswami, 2007**). A noticeable decline in rainfall was recorded between 2001 and 2010, particularly in Pollachi, Sulur, and Annur, due to urbanization, land-use changes (**Kumar *et al.*, 2010**), and vegetation loss in areas like Peelamedu and Coimbatore South (**Shepherd, 2005**). Low rainfall in Annur and Sulur is linked to the rain shadow effect (**Jayakrishnan *et al.*, 2013**), while high rainfall in Valparai and Aliyar results from orographic lifting (**Guhathakurta & Rajeevan, 2008**). Valparai Pap's rainfall is primarily monsoon-driven, with a temporary winter increase during 2001–2010 likely influenced by ENSO and the Indian Ocean Dipole. Declines in pre-monsoon rainfall may be attributed to regional warming and deforestation.

The Mann- Kendall test indicated stable rainfall trends across most stations except for a winter shift at Mettupalayam. Sen's Slope analysis showed slight increasing trends at Pollachi and TN-Agri, possibly due to microclimatic changes or reforestation (**Dash et al., 2009; Kulkarni et al., 2012**). During 2011–2020, Mettupalayam recorded the highest annual rainfall (1303.89 mm), followed by Periyanaiken Palayam and TN-Agri, each exceeding 1260 mm. In contrast, Pollachi showed the lowest rainfall (1112.81 mm), with Sulur and Peelamedu also receiving comparatively lower rainfall. These spatial and seasonal variations highlight the need for localized water management strategies, such as promoting irrigation and climate-resilient crops in drier regions like Peelamedu and rainwater harvesting in high-rainfall areas like Valparai (**IWMI, 2007; MoES, 2018**).

5. CONCLUSIONS

This study examined the spatial and temporal variability of rainfall across 14 stations in Coimbatore district over the period 1991–2020, using statistical methods such as the Mann-Kendall Test, Sen's Slope Estimator, and Mann-Whitney Pettit Test. The analysis revealed mostly stable rainfall trends across the district, with seasonal variations notably observed at Metupalayam. Sen's Slope results indicated increasing rainfall at Pollachi and Valparai during 2011–2020, while

Metupalayam showed a declining trend. Seasonal rainfall patterns varied across stations, with Aliyar receiving the highest Pre-Monsoon rainfall, Sulur in Monsoon, and Valparai Chinnakalar and Pap in Post-Monsoon. Spatial analysis through IDW and Kriging methods identified higher rainfall in Aliyar, Valparai, and Sulur, while lower rainfall was recorded in Pollachi, Peelamedu, and Annur.

These spatial and seasonal differences highlight the need for localized water management strategies. Declining rainfall in areas like Pollachi and Sulur may lead to water scarcity, while increasing rainfall in Pollachi and Tn-Agri may enhance water availability but raise flood risks. The study emphasizes the importance of adaptive water management, climate-resilient infrastructure, and sustainable agricultural practices to address the region's changing rainfall patterns and ensure long-term environmental stability.

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