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Trend and Variability Analysis of Rainfall in Thrissur Corporation

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***Abstract*—Rainfall has a great impact on the livelihood of people in subtropical countries like India. Changes in precipitation impact people and the ecosystem by altering the availability of water throughout the year. Therefore, trend analysis of rainfall has much importance in examining climate change and better planning and management of resources.The present study aimed to analyze the trend and variability of rainfall, over a period of 29 years (1991 to 2019) of Thrissur Corporation in the state of Kerala, India. In this study, the analysis was done with parametric and non-parametric methods like Mann-Kendall tests, Sen's slope estimator and Regression analysis. Mann-Kendall tests were used to find the trend in the variability of rainfall, over the period of observation using XLSTAT software. The magnitude of variation was detected using Sen's slope estimator. The annual and winter season rainfall were found to have a non-significant increasing trend with a positive Sen's slope, while rainfall during summer, North-East monsoon and South-West monsoon seasons have a non-significant decreasing trend. The analysis of the impact on rainfall by temperature and relative humidity using the method of linear regression in MATLAB and SPSS software revealed a non-significant correlation of 13.8%. The results thus reveal that temperature and relative humidity have a very low impact on rainfall Of Thrissur Corporation. Other meteorological parameters like wind, solar radiation, ocean currents and factor like land use changes may influence the rainfall to a greater extent.**

***Index Terms*— Rainfall, Thrissur Corporation, Climate, Trend analysis, Variability.**

I. INTRODUCTION

Climate change has become a global concern over the last few decades. Climate change prolongs to a long period, causing weather changes and leads to imbalance of natural habitat. Extreme weather can impact human health, limiting access to drinking water, food and ability to cope with the heat, drought and flood. Rainfall and temperature are two critical factors that have significant impacts on climate change. Timely monitoring and interpreting climatic variations, especially rainfall and temperature is necessary for the management of water resources and disaster of an area. This also helps in minimizing the drastic variation in climatic variables and brings the data to predictive level for future forecasting. The predicted information can be utilized by crop and livestock producers and agribusinesses to adapt to and minimize the impact of changing weather patterns.

To detect the climatic changes and recommend remedial measures, trend analysis is a useful and effective statistical method. Several recent studies show that trends in rainfall and temperature have significant effects on climatic changes. The long-term trend analysis of rainfall was carried out using the widely used Mann- Kendall

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test and Sen's slope estimator provided the magnitude of the trend in most of the studies.
Changes in rainfall patterns and characteristics at a regional scale on agro-climatic zone basis, in the mid-Mahanadi river basin showed that there was large spatiotemporal variation in the river basin with a shift in seasonality of rainfall, increased prolonged dry spells and significant increase in extreme weather events. The main reason for the spatial variation in seasonal rainfall was attributed to the geographical location of Odisha state, having a long sea coast [1]. Rainfall variability and trend at regional level of Kerala showed a significant ($\leq$0.01) decreasing trend in most of the regions of Kerala. The decreasing trend may be related to global anomalies as a result of anthropogenic activities [2]. A new type of neural network, the adaptive basis function network was found as a promising tool for rainfall analysis in Kerala State which disclosed certain periodicities in long-term behavior. Most of the deviations in the periodicity were related to solar cycles, variations in ocean currents and wind directions, sea surface temperature anomalies, etc. The result revealed that in spite of the fluctuations resulting from the nonlinearity in the system, the trends in the rainfall pattern in Kerala state remained unaffected over 87 years from 1893 to 1980 [3].Trend in rainfall and temperature over Kalahandi, Bolangir and Koraput districts in the state of Odisha showed a quite good increasing trend for 37 years during the period of 1980–2017 [4]. Significance of the potential trends of rainfall, temperature and runoff over the Rangoon watershed in Dadeldhura district of Nepal during the period between 1979 to 2010 inferred that monsoon and post-monsoon period showed a positive rainfall trend, whereas pre-monsoon and winter seasons showed a negative trend in rainfall [5].
This study has been attempted to investigate the trend of climatic variable, rainfall of Thrissur Corporation and find the correlation between the parameters viz rainfall, temperature and relative humidity using statistical analysis methods. The time series trend and variability in rainfall over the period were analyzed using the non-parametric method, the Mann-Kendall test. Various statistical parameters like trend probability, standard-deviation, Sen's slope, etc. were used to define the trend pattern of rainfall, over the observation period. The effect of temperature and relative humidity on rainfall patterns were analyzed through method of linear regression.

II. METHODOLOGY

A. Study Area

Thrissur Corporation in the state of Kerala is located at 10.52°N and 76.21°E. It has undergone rapid growth in urbanization over the past decades. The number of urban settlements of the district has been increasing from 1991to 2019, the steady growth making changes in natural habitat and many built-up areas, probably contributing to significant changes in climatic parameters. Fig. 1 shows the location map of Thrissur Corporation. Thrissur Corporation has a tropical humid climate with an oppressive hot season and plentiful seasonal rainfall.

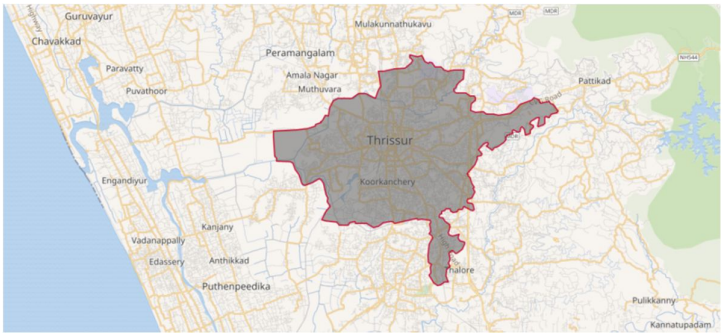

Figure 1. Location map of Thrissur Corporation

B. Trend analysis

The monthly rainfall, humidity, and mean temperature data of Thrissur Corporation, for the period 1991-2019 were collected from the NASA Prediction of Worldwide Energy Resources website. The Mann Kendall test and Sen's slope estimator were used to analyze the trend in rainfall for the years 1991 to 2019. The trend analyses were done for winter, summer, N E monsoon,S W monsoon seasons, and also on annual basis. For conducting trend analysis based on decades, the period of time 1991-2019 was divided into three (1991-200, 2001-2009, 2010-2019).

C. Mann Kendall test

Mann-Kendall (M-K) trend test is a nonparametric test used to identify trend in a series. The Mann-Kendall test is based on the calculation of Kendall's tau measure of association between two samples, which itself is based on the ranks of the samples [6].

The Mann-Kendall test statistic is given by:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Sgn(x_j - x_i) \qquad (1)$$

Where n is the number of data points. Assuming (xj-xi) = θ, the value of Sgn(θ) is computed as follows:

$$sgn(\theta) = \begin{cases} 1 \; if \; \theta > 0 \\ 0 \; if \; \theta = 0 \\ -1 \; if \; \theta < 0 \end{cases} \qquad (2)$$

The statistics represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (n>10), the test is conducted using a normal distribution, with variance as follow.

$$V(s) = \frac{n(n-1)(2n+5)}{18} \qquad (3)$$

Where n is the number of observations and x_i (i =1…n) are the independent observations.

D. Sen's slope

Sen's slope estimation is another non-parametric method for trend analysis of hydro-climatic data set. It is used to detect the magnitude of the trend by determining the slope 'T_i' between any two values.

$$Ti = \frac{xj - xi}{j - i} \qquad \text{For } i=1, 2, 3,\ldots,N \qquad (4)$$

Where x_j and x_i are the data values for j and i over the time when j> i. The slope is estimated for each observation. Median is computed from N observations of the slope to estimate the Sen's Slope estimator:

$$Q_i = T\frac{N+1}{2} \quad For\ N\ is\ odd \qquad (5)$$

$$Q_i = \frac{1}{2}\left[T_{\frac{N}{2}} + T_{\frac{N+1}{2}}\right] \quad For\ N\ is\ even \qquad (6)$$

The two-sided test is carried out at 100(1 – α) % of the confidence interval to obtain the true slope for the non-parametric test in the series [7]. The positive or negative slope Q_i is obtained with a significance (α) of 5%. as an upward (increasing) or downward (decreasing) trend

E. Regression analysis

The goal of linear and nonlinear regression is to adjust the values of the parameters to find the best fit for defining the relationship between them. Regression analysis was performed using software IBM SPSS® and MATLAB. In SPSS, Multiple linear regression was carried out with relative humidity and temperature as independent variable, and rainfall as dependent variable. The MATLAB Basic Fitting UI helps to fit the data for calculating model coefficients and plotting the relationship. Depending on the value of R^2, linear, exponential or polynomial degree functions were selectedand function with the highest R^2 value was used as the best fit model.

III. Results and Discussions

A. Trend analysis of rainfall

The M-K test and Sen's slope estimator were applied to the time-series data of rainfall from 1991 to 2019 for Thrissur Corporation. The mean annual rainfall of the area during the study period is 2147.490 mm with 437.494 mm standard deviation and 20.37% coefficient of variance (CV). The minimum and maximum recorded rainfalls were 1371.38 mm (in 2011- the driest year) and 3312.2 mm (in 2019-the wettest year) per year respectively.

The results of M-K test for trend analysis are presented in Table I. The trend analysis was done for precipitationdata during, winter, summer, N E monsoon, S W monsoon season and the whole year. In all cases, there is no trend in

the series because the p-value is greater than the required threshold value (0.05). The annual and winter season have a non-significant increasing trend in precipitation with a Sen's slope of 10.446 and 0.015 respectively, while the remaining seasons, summer, N E monsoon and S W monsoon have a non-significant decreasing trend with Sen's slopes of -0.094, -2.827 and -2.350 respectively. In a similar study conducted in Kerala, comprising of six gridded areas over the period of 1954 to 2003 revealed that winter season had an increasing tendency and summer season had a decreasing trend in rainfall pattern over the period of study [8].

For conducting trend analysis on the basis of decade, the period of time1991-2019 was divided into three (1991-2000, 2001-2009, and 2010-2019). The results are presented in table II. The average annual rainfall for the period 2001-2010 (mean=2251.050 mm; SD=354.001mm) is higher than the mean annual rainfall of the area for the period 2010-2019 (mean=2146.346mm; SD=635.501mm), while the period 1991-2000 has the least meanannual rainfall (mean=2044.961mm; SD=295.917mm). The results reveal that rainfall per decade increased during 1991-2010 and decreased in 2010-2019. The only case where a trend can be observed is in the S W monsoon season (p=0.047) of 2001-2009. A significant increasing trend in precipitation is obtained during the period. The average rainfall during the period was 1108.112mm with 215.109 mm standard deviation and 19.46 % CV.

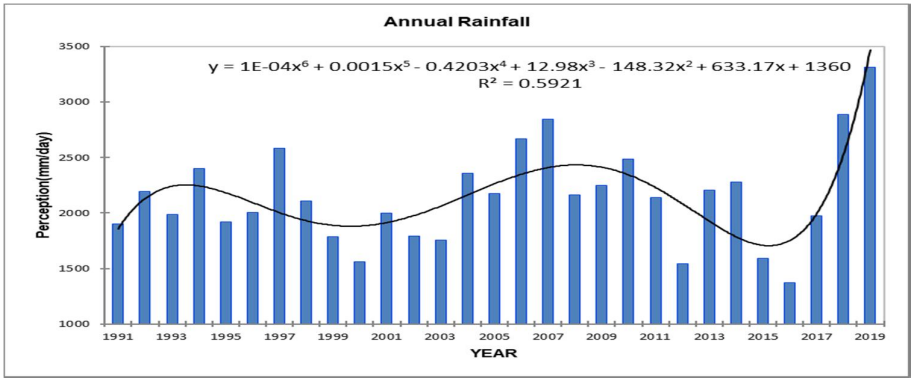

Figure 2. Polynomial rainfall trend of annual precipitation

TABLE I. M-K TEST RESULTS OF RAINFALL FOR 1991-2019

	p- value	Sen's slope	Mean (mm)	S.D. (mm)
Annual	0.402	10.446	2147.490	437.494
Winter	0.724	0.015	37.568	29.415
Summer	0.112	-0.094	308.217	132.510
NE monsoon	0.492	-2.827	412.222	123.501
SW monsoon	0.809	-2.350	1186.299	345.254

B. Regression Analysis

Table III shows the results obtained for linear regression analysis using the MATLAB software. In the regression analysis between, rainfall and temperature and rainfall and relative humidity, no correlation is observed as p-value is greater than the threshold value (0.05). Thus temperature and relative humidity have non-significant effect on the rainfall rate over the period of observation. The correlation between the rainfall and temperature increases for a poly-linearregression analysis with R^2 value of 0.388 and RMSE of 0.287. The relation between rainfall and relative humidity is best at sixth degree polynomial with a R^2value of 0.349 and RMSE of 1.1452.The results obtained for linear regression analysis using SPSS software is shown in the Table IV. The parametersare non-significantly correlated and obtained p-value greater than the threshold value (0.05). The surface temperature has a very less and non-significant impact over rainfall (0.1%), which means they are least correlated.while the effect of relative humidity over rainfall is 9.7%.The combined effect of both relative humidity and temperature on rainfall is also found non-significant.

C. Other factors affecting rainfall

There are various other factors influencing rainfall like global warming, water bodies, topographical influences (the shape of land), distance from the sea, ocean currents, direction of prevailing winds, anthropogenic activities etc. Winds that blow from Arabian Sea often bring rain to the coastal and dry weather to inland areas. Low pressure systems which form in Arabian Sea cause high rainfall in Kerala [9]. Activities of human such as deforestation, urbanization also affects the variation of rainfall. Greenhouse gas emissions and land use change are

TABLE II. M-K TEST RESULTS OF RAINFALL DATA FOR DECADE

	p- value	Sen's slope	Mean (mm)	S.D. (mm)
1991-2000				
Annual	0.601	-34.065	2044.961	295.917
Winter	0.291	4.11	51.364	40.757
Summer	0.601	15.22	217.521	99.744
S W monsoon	0.073	-55.947	1209.375	273.722
N E monsoon	0.727	3.655	409.811	120.261
2001-2010				
Annual	0.108	81.556	2251.050	354.001
Winter	0.484	1.448	28.866	19.544
Summer	0.727	-4.881	406.484	137.561
S W monsoon	0.047	36.146	1108.112	215.109
N E monsoon	0.727	4.441	471.369	100.921
2011-2019				
Annual	0.260	121.425	2146.346	635.51
Winter	0.761	2.391	31.908	19.006
Summer	0.761	-2.843	299.804	80.888
S W monsoon	0.358	99.045	1250.868	516.974
N E monsoon	0.761	5.681	349.183	129.631

key factors in extreme precipitation events. Studies incorporating these factors will give greater insights to the rainfall pattern in an area.

TABLE III. LINEAR REGRESSION ANALYSIS USING MATLAB SOFTWARE

Parameter	No. of observations	p- value	R^2 value	RMSE (%)
Rainfall-Temperature	29	0.866	0.00107	0.331
Rainfall- Relative humidity	29	0.0997	0.0972	1.22

TABLE IV. LINEAR REGRESSION ANALYSIS USING SPSS SOFTWARE

Parameter	No. of observations	p- value	R^2 value	Standard error (mm)
Rainfall-Temperature	29	0.866	0.001	445.28
Rainfall- Relative humidity	29	0.1	0.097	423.319
Rainfall: -Temperature -Relative humidity	29	 0.275 0.052	0.138	421.417

IV. CONCLUSIONS

Long term trend analysis was done (29 years) for annual and seasonal data of rainfall of Thrissur Corporation. The results show that there is no significant trend existing for rainfall in the area. While considering the trendof rainfall over decades, the south-west monsoon rainfall over the time period of 2001-2010 shows a significant trend with positive slope. The impact of surface temperature and relative humidity over the rainfall amount were analyzed using method of linear regression using MATLAB and SPSS. The analysis results by both software show that there is non-significant correlation and impact on rainfall due to temperature and relative humidity. The combined effectof both temperature and relative humidity on rainfall data over the study period was 13.8%, which reveals that thevariation in rainfall may be affected by a number of other factors to a larger extent. Hence analysis of various factors like wind effect, deforestation, urbanization etc. and their impact on rainfall variation is a future scope of this study.

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