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Research Article

SPATIAL AND TEMPORAL VARIABILITY OF PRECIPITATION CONCENTRATION INDEX (PCI) AND RAINFALL TREND FOR PARAMBIKULAMALIYAR BASIN AREA TAMIL NADU

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Abstract: This paper presents the trend in the annual rainfall and its distribution over Parambikulam Aliyar basin of Tamil Nadu determined using 30 years (1988-2008) monthly rainfall data at 28 rain-gauge stations. The trend analysis was done by using Mann-Kendall test. The results indicated increasing trends in annual rainfall. The mean Precipitation Concentration Index of Valaiyar sub basin and Palar sub basin indicates strongly irregular monthly distribution of annual rainfall. The mean Precipitation Concentration Index of Aliyar sub basin and Sholaiyar sub basin indicates irrugular monthly distribution of annual rainfall. The temporal pattern of rainfall trends analyzed in this study is a basic and important requirement for agricultural planning and management of water resources.

Keywords: Precipitation Concentration Index, Parambikulam Aliyar basin, Monthly distribution, Mann Kendal Analysis

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Introduction

Precipitation is one of the most important climate elements directly affecting the availability of water resources [1]. In order to understand the behaviour of ecosystems in semi-arid areas, rainfall must be analysed over time. The amount and temporal distribution of rainfall is generally the single most important determinant of inter annual fluctuations in national crop production levels [2]. The Precipitation Concentration Index (PCI) is a powerful indicator of the temporal distribution of precipitation, traditionally applied at annual scales; as the value increases, the more concentrated the precipitation. The linear relationship is the most common method used for detecting rainfall trends [3]. On the other hand, the Mann–Kendall (MK) test has been widely used to evaluate a presence of a statistically significant trend in hydrological and climatologically time-series [4-8]. The aim of the study is to analyse rainfall variability at annual and seasonal time scales using by PCI and to analyse the trend of annual rainfall by Mann-Kendal test. This paper presents the trend in the annual rainfall and its distribution over Parambikulam Aliyar basin of Tamil Nadu which is a basic and important requirement for agricultural planning and management of water resources.

Materials and Methods

The Study Area

PAP basin is located in the south western part of the Peninsular India covering areas in Kerala and Tamil Nadu States. It is grouped into four sub basins such as Valaiyar sub basin, Aliyar subbasin, Palar sub basin, and Solaiyar sub basin and spread over an area of 2388.72 km^2. PAP has an undulating topography with maximum contour elevation in the plain is 300 m and the maximum spot height in the plain is 385 m above MSL. This basin area lies (except the Ayacut area) within the coordinates of North latitude between 10°10'00" to 10°57'20" and East longitudes 76°43'00" to 77° 12'30" [9]. The Sholaya river originates from eastern slope of Western Ghats of Coimbatore District. The drainages namely the Parambikulam Aliyar, Upper Sholayar and Lower Sholayar passes through Valparai Block which has an area of about 403Km^2.

This sub basin is covered with high hills and dense forest cover. The predominant type of rock found in this sub basin is crystalline rocks of Archean age. River Palar originates in the eastern slope of Western Ghats from Anamalai hills and passes through Gudimangalam, Pollachi, Udumalpet blocks. The soil in this area is pediment, pediment with block cotton soil and shallow pediments. The area of the Sub basin is 475 km^2. Aliyar River originates from Anamalai hills and passes through Kottur village and joins at Aliyar Reservoir of Coimbatore district. The Aliyar Reservoir is located along major lineaments. The major area present here is denudation forms such as pediment, pediment with black cotton soil and shallow pediments. The alluvial landforms such as bazadas occur along the foot hills of Anamalai Hill ranges in western Ghats. This Sub basin has an ayacut area of 402 km^2. Valayar River originates from Thondamuthur block and passes through Madukkarai block and joins at Walaiyar reservoir in Coimbatore District. It has an area of about 846 km^2.

Fig-1 Location of study area

Precipitation Concentration Index (PCI)

To define the degree of inter-annual variability in rainfall, together with its temporal evolution along the study period, a modified version [10] of the precipitation concentration index (PCI) was applied according to the proposal of [11].

$$PCI = \frac{\sum_{I=1}^{12} P^2}{(\sum_{I=1}^{12} P^2)}\ 100 \qquad 1$$

Where, Pi is the amount of precipitation of the month i,

Table-1 Weather Station with Coordinates Selected For PAP Studies

SN	Station	Taluk	Latitude	Longitude	Duration
1	Aliyar Nagar	Pollachi	10⁰ 29' 10"	76⁰ 58' 00"	1972-2008
2	Weaverly	Pollachi	10⁰ 24' 30"	76⁰ 59' 43"	1972-2008
3	Vettaikaranputhur	Pollachi	10⁰ 33' 05"	76⁰ 55' 05"	1972-2008
4	Varattuparai	Pollachi	10⁰ 22' 10"	76⁰ 54' 50"	1972-2008
5	Valparai	Valparai	10⁰ 19' 35"	76⁰ 57' 07"	1972-2008
6	Upper Nirar	Pollachi	10⁰ 18' 04"	77⁰ 01' 22"	1972-2008
7	Udumalpet	Udumalpet	10⁰ 35' 00"	77⁰ 15' 00"	1936-2008
8	Topslip	Valparai	10⁰ 28' 10"	76⁰ 51' 00"	1972-2008
9	Thunakadavu	Pollachi	10⁰ 26' 10"	76⁰ 46' 40"	1972-2008
10	Thirumoorthy Nagar	Udumalpet	10⁰ 29' 10"	77⁰ 09' 20"	1972-2008
11	Sulthanpet	Coimbatore	10⁰ 52' 15"	77⁰ 12' 00"	1976-2008
12	Sholaiyar	Valparai	10⁰ 18' 10"	76⁰ 52' 50"	1972-2008
13	Poolankinar	Udumalpet	10⁰ 35' 25"	77⁰ 11' 50"	1983-2008
14	Pollachi	Pollachi	10⁰ 39' 40"	77⁰ 00' 30"	1936-2008
15	Podanur	Coimbatore	10⁰ 58' 00"	76⁰ 59' 40"	1980-2008
16	Pedappampatti	Udumalpet	10⁰ 40' 40"	77⁰ 13' 15"	1973-2008
17	Parambikulam	Pollachi	10⁰ 23' 30"	76⁰ 46' 30"	1972-2008
18	Negamam	Pollachi	10⁰ 44' 56"	77 06' 10"	1972-2008
19	Nattakalapalayam	Pollachi	10⁰ 37' 45"	77⁰ 03' 00"	1959-2008
20	Nallar	Udumalpet	10⁰ 33' 50"	77⁰ 04' 50"	1972-2008
21	Lower Nirar	Pollachi	10⁰ 18' 40"	76⁰ 57' 07"	1976-2008
22	Krishnapuram	Udumalpet	10⁰ 55' 10"	77⁰ 13' 10"	1959-2008
23	Amaravathy Nagar	Udumalpet	10⁰ 25' 51"	77⁰ 15' 30"	1972-2008
24	Iyerpadi	Pollachi	10⁰22'15"	76⁰58'30"	1983-2008
25	Gomangalam	Udumalpet	10⁰ 37' 14"	77⁰ 09' 00"	1988-2008
26	ChinnaKallar	Pollachi	10⁰18'00"	77⁰ 02' 00"	1962-2008
27	Attakatti	Pollachi	10⁰ 26' 40"	76⁰ 59' 10"	1962-2008
28	Anamalai	Pollachi	10⁰ 34' 50"	76⁰56'05"	1936-2008

Table-2 Precipitation Concentration Index (PCI) classification by Oliver.

PCI value	Distribution of precipitation
PCI < 10	Uniform precipitation distribution
11 - 20	Moderate precipitation concentration
16 - 20	Irregular distribution
PCI>20	Strongly irregular distribution

Mann-Kendall Test (MK test)

The MK test, usually used to assess the trend of a time-series, was applied by considering the statistic S as:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} sign(x_j - x_i) \quad 2$$

Where xj and xi are annual values in years j and i, j>I respectively, and N is the number of data points. the value of sign (xj-xi)

$$sign(x_j - x_i) = \begin{cases} 1 \; if sgn(x_j - x_i) > 0 \\ 0 \; if sgn(x_j - x_i) = 0 \\ -1 \; if sgn(x_j - x_i) < 0 \end{cases} \quad 3$$

This 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 approximation (Z statistics) with the mean and the variance as follows:

E(S) = 0 4

Here q is the number of tied (zero difference between compared values) groups, and tp is the number of data values in the p th group. The values of S and VAR(S) are used to compute the test statistic Z as follows

The standardized statistical test (Z) was computed by:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var\,(S)}} \; if \; S > 0 \\ 0 \qquad if \; S = 0 \\ \frac{S+1}{\sqrt{Var\,(S)}} \; if \; S < 0 \end{cases} \quad 5$$

The presence of a statistically significant trend is evaluated using the Z value. A positive value of Z indicates an upward trend and its negative value a downward trend. The statistic Z has a normal distribution. To test for either an upward or downward monotone trend (a two-tailed test) at α level of significance, H0 is rejected if the absolute value of Z is greater than Z1-α/2, where Z1-α/2 is obtained from the standard normal cumulative distribution tables. The Z values were tested at 0.05 level of significance. The Mann-Kendall statistical analysis has been found to be an excellent tool for trend detection in different applications [12]. The Mann-Kendall non-parametric test was applied to the hydro-meteorological variables in the Niger River and the Benue sub-basins [13].

Result and Discursion

Rainfall Analysis

The total annual rainfall in PAP is 1766 .06 mm from the year 1988 to 2008.the trend in rainfall is shown in figure 1. The raising trend is observed in the rainfall.

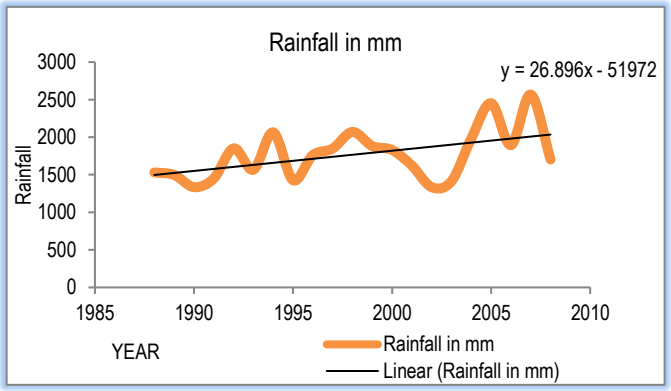

Fig-2 Trend in annual rainfall (1988-2008)

Analysis of trend in rainfall and its distribution for PAP Sub basin

Valaiyar Sub basin

The total annual rainfall in Valaiyar sub basin is 639.1 mm from the year 1988 to 2008.The trend in rainfall is shown in figure 2.the raising trend is observed in the rainfall.The mean PCI is 21.19, indicates the strongly irregular monthly distribution of annual rainfall in Valaiyar sub basin for the year of 1988-2008.

Aliyar sub basin

The total annual rainfall in Aliyar sub basin is 1647 mm from the year 1988 to 2008.the trend in rainfall is shown in figure 3.the raising trend is observed in the rainfall. The mean PCI is 17.84. It indicates irregular distribution of annual rainfall in Aliyar sub basin for the year of 1988-2008.

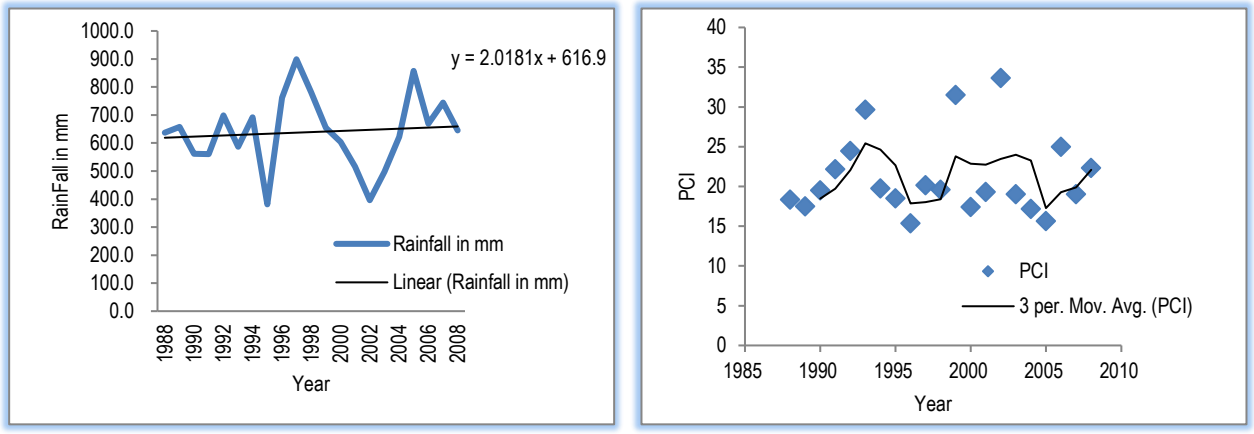

Fig-3 Trends in rainfall and PCI of Valaiyar sub basin (1988-2008)

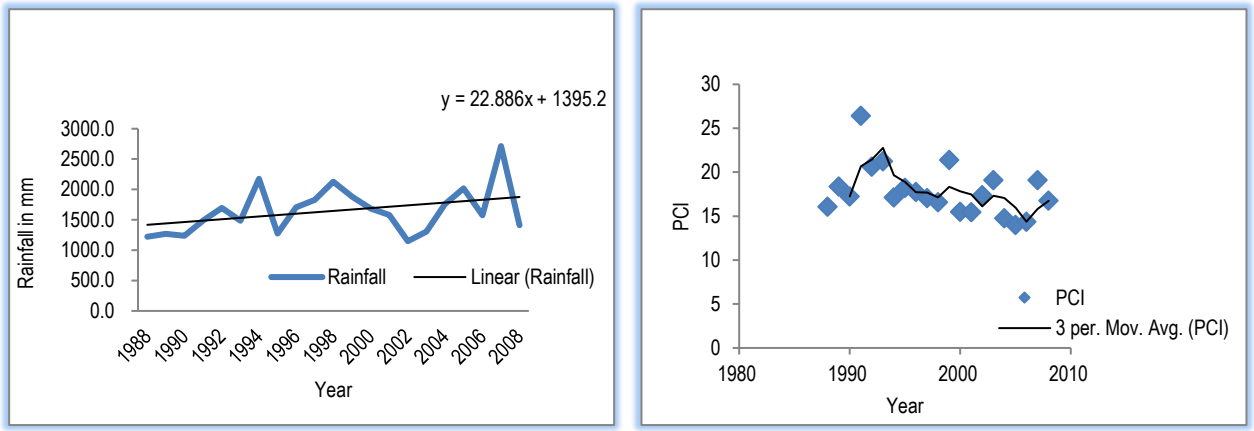

Fig-4 Trends in rainfall and PCI of Aliyar sub basin (1988-2008)

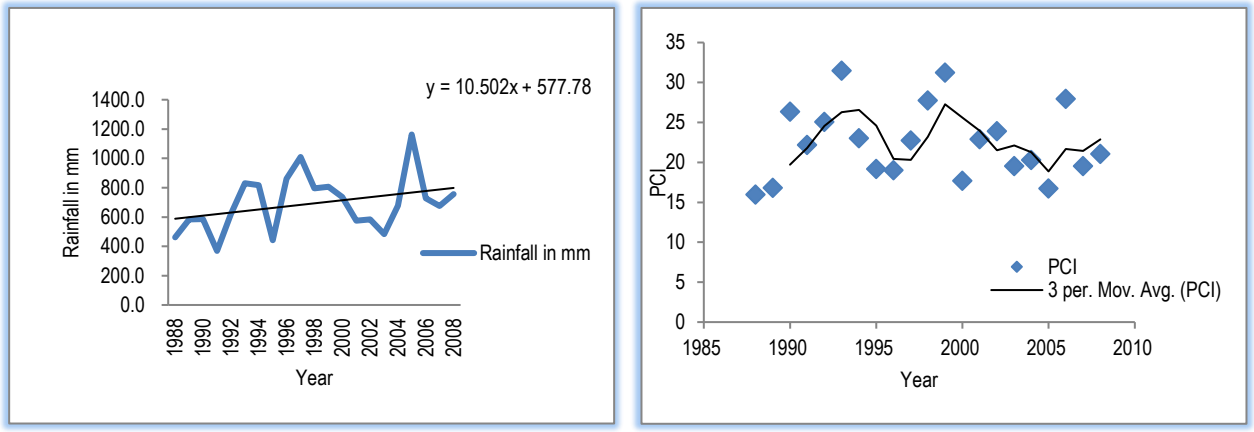

Fig-5 Trends in Rainfall and PCI of Palar sub basin (1988-2008)

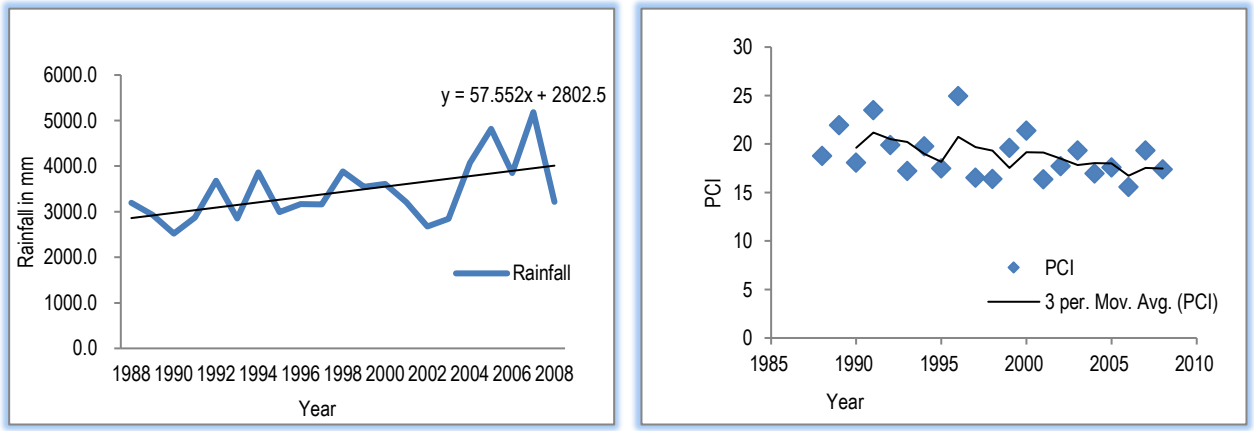

Fig-6 Trends in Rainfall and PCI of Sholaiyar sub basin (1988-2008)

Palar sub basin

The total annual rainfall in Palar sub basin is 639.3 mm from the year 1988 to 2008.the trend in rainfall is shown in figure 4.the raising trend is observed in the rainfall. The mean PCI is 22.41. It indicates the strongly irregular monthly distribution of annual rainfall in Palarsub basin for the year of 1988-2008.

Sholaiyar sub basin

The total annual rainfall in Sholaiyar sub basin is 3435.3 mm from the year 1988 to 2008. The trend in rainfall is shown in figure 5. The raising trend is observed in the rainfall. The mean PCI is 18.21 it indicates the irregular distribution of annual rainfall in Sholaiyar sub basin for the year of 1988-2008.

PCI of PAP

A good knowledge of critical values of the series of various climatic elements such as rainfall and some of their derived indexes is of great importance in detecting variability which has implications for water resource planning and management, disaster preparedness etc. this study underscores the usefulness of PCI in detecting precipitation concentration and variability. The decreasing trend is observed in PCI .The falling Trend in PCI is given in figure 5. It was observed based on the plot for rainfall and PCI that this climatic variable and the associated index are changing. On annual scales, PCI was found to range from the lowest value of 12 in 1976 to the highest, for the 38 years period under study, of 20 in 1987. The mean PCI of PAP Basin is observed as 20.16. It is indicate strongly irregular monthly distribution of annual rainfall for the year of 1988-2008.This implies that rainfall pattern in the study area is not uniformly distributed but had fluctuated between certain seasonal distribution and irregular distribution range. Also, there is needing to further investigate the spatial variability in PCI value on all scales for PAP and its region given that precipitation is spatially highly variable.

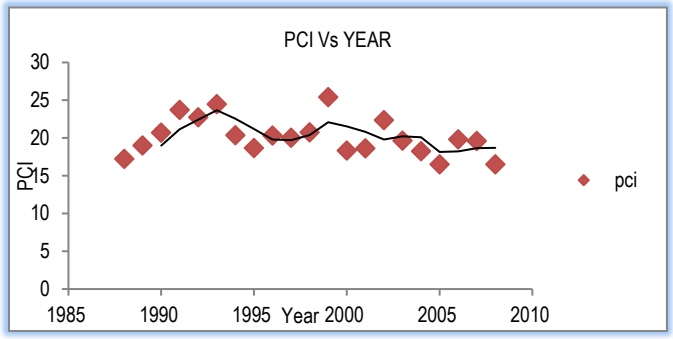

Fig-7 PCI (Dots) and 3 year moving average of PAP Basin

Mann-Kendall Analysis

The Mann-Kendall test indicates the increasing trend of rainfall in PAP Basin since 1988.In the PAP Basin, the analyses of precipitation have positive Kendall's (Z) values, which indicate that all the variables have positive trend.

Table-3 Mann Kendall results for PAP

Variable	Z value	Trend	Significance
Rainfall	2.19	Positive	Yes

Conclusions

Climatic variations are observed in almost most regions at the global and regional level. This study attempted to analyze the trend in rainfall and its distribution in PAP Basin for the period of 1972-2008 using by 28 rainfall station data. Based on the result above, annual rainfall in PAP is not uniformly distributed but can be characterized as being of seasonal precipitation to irregular precipitation distribution in most of the years and strongly irregular in others. Mann-Kendall test is given as increase trend in Rainfall since 1983.The knowledge of temporal pattern of rainfall trends analyzed in this study is a basic and important requirement for agricultural planning and management of water resources. The implications of such observed change have strong influence on natural process of soil erosion, flooding regimes and groundwater recharge. It is, therefore, recommended that the local authorities and decision making personnel should take cognizance of this result in the planning of the new layouts and redevelopment of the old areas of the town. PCI can, therefore, serve as a warning tool for flooding and erosion within PAP and environs.

Application of Research: Concluded result will help researcher to do further studies in temporal pattern of rainfall trends to be analysed for agricultural planning and management of water resources.

Abbreviations:

PCI: Precipitation Concentration Index
PAP: Parambikulam Aliyar basin Project
MSL: Mean Sea Level
MK test: Mann-Kendal test.

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Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

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Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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