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Spatial and Temporal Trend Analysis of Rainfall Distribution in Nambiyar Watershed, Tamil Nadu

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Abstract

This study is an attempt to comprehend the spatial and temporal trend of rainfall distribution in the Nambiyar watershed. The daily rainfall data was processed for the period from 1988 to 2018 to map the spatial distribution and analyse the temporal trend of rainfall. The results reveals that mean annual rainfall received in the watershed is 1026.81 mm. Statistical techniques like Mann- Kendall test and Sen's Slope estimator were used to analyse presence of trend and correlation of variables. Among four seasons northeast monsoon contributes around 47 per cent (482.57 mm) of the total rainfall. The results brought out the fact that annual rainfall of the watershed does not exhibit any significant trend at α=0.05 or 95% of confidence level. Agricultural and allied activities which requires adequate irrigation is determined by the rainfall received in this watershed. Hence this study brings out the spatial and temporal pattern of rainfall distribution in Nambiyar watershed.

Keywords: Rainfall trend; GIS; Sen's slope; Mann-Kendall test

Introduction

Fresh water is a basic resource needed for the sustenance of life on earth for all living beings. Rainfall is the major source of fresh water on the earth's surface. It is also an important form of water that enters a drainage basin which governs major functions of an ecosystem. The amount of precipitation falling over unit area depends on the latitude and altitude of the watershed (Ion, 1985). Indian subcontinent lies in the tropical zone and exhibits variation in its rainfall distribution in spatial and temporal dimension based on its location, physiographical setting etc. Evaluation of water resources have emerged as a particular concern since water is inevitable resource needed for maintaining the productivity of land (Hassan et al. 2009). The analysis of rainfall distribution, rainfall intensity and variability in terms of annual, seasonal, and monthly range is useful for estimating the average recharge rate of rainfall in a region (Krishnaiah, 2014).

Spatial and temporal analysis of rainfall is effective for identifying the probability of occurrence of extreme rainfall events (Hinge, 2021). Most of the states in India receive rainfall during South West monsoon season with an exception being Northwest monsoon season contributes more to annual rainfall in Tamil Nadu (Sridhar et al. 2017). The annual, seasonal and monthly trend analysis of weather elements such as rainfall, temperature, relative humidity etc. provides an insight to overall rainfall distribution pattern which is considered as inevitable for watershed management (Pal et al.2017). Geospatial and statistical tools enable user to recognize the pattern, distribution of a particular phenomenon by analyzing the ongoing and predicting the future trend of the same (Praveen et al. 2020). The irregularity in the temporal distribution of the rainfall can be analysed through the many statistical techniques like Mann-Kendall, Kruskal Wallis test etc (Jorio et al. 2020). Any change in the precipitation amount has a significant impact in the hydrological cycle and functioning of ecosystem (Anie et al.2018). Trend analyses of the rainfall provide an insight to existing groundwater recharge pattern and also thereby enhance need of rainwater harvesting methods (Vartika et al. 2012). Also the variability and trend of rainfall are indicators of risk in global climate change and water resources management (Terence, 2006). Since the agriculture in India mostly rely on irrigation it is essential to analyse the rainfall in terms of temporal dimension like annual, seasonal, monthly and daily rainfall amount. Statistical techniques especially non-parametric test are widely used in trend analysis of rainfall distribution since it can recognize the outliers in the data (Das et al.2019). The statistical test like Mann-Kendall test is most versatile to find out the increasing and decreasing trend of rainfall over larger period of time which reflects the dynamics in weather elements (Parthsarathy et al. 1975). Stochastic modeling especially Markov Chain analysis which has been carried out to predict the rainfall pattern of the Tirunelveli District up to the year 2025 reveals the probability of variability in the annual rainfall pattern (Paliah, 2018). Machine learning approach like Artificial Neural Network-Multilayer Perceptron (ANN-MLP) and non-parametrical test like Mann-Kendall, Sen's Slope estimator are used for analyzing spatial temporal aspects and also predict the future trend of rainfall distribution (Praveen et al.2020). Temperature and rainfall are unevenly distributed over a region and are some of the important required variables in all stages of crop growth which makes. This makes measuring its quantity and availability to crops inevitable by using various statistical techniques (Gadedjisso-Tossou et al. 2021). Hence, this study aims to bring out spatial and temporal trend of rainfall distribution over the Nambiyar watershed.

Study Area

Nambiyar watershed lies to the southwestern part of Tirunelveli District of Tamil Nadu, India. It extends from 8° 10'N to 8° 32'N latitudes and 77° 28'E to 77° 50'E longitudes. The basin covers an area of 665.45 sq.km (66545.98 ha). The source of the river is located at Kalakkadu Reserved Forest which is a part of Western Ghats with an altitude of 1800m. The river flows towards eastern direction and enters the plains at Thirukurangudi and finally drains into Gulf of Mannar in Bay of Bengal. Kodamadi Ar, Paratai Ar, Tamarai Ar, Valliyuran kal and Kallan odai are the major tributaries of the Nambiyar River. The drainage patterns of streams are reveals it is dendritic in nature. The watershed possesses a unique locational setting by spanning across hilly terrain extending upto coastal plains. The dominant rock type found in this region is Gneiss composed of a variety of minerals. The watershed falls within Nanguneri, Radhapuram, Tisayanvilayi taluks covering about 58 revenue villages which forms the administrative unit of the Tirunelveli District. The location of the study area map is shown in Figure 1.

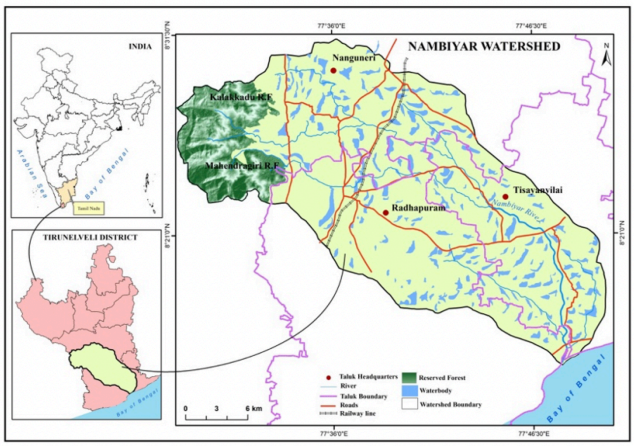

Fig. 1. Locationof Nambiyar Watershed

Materials and Methods

In the present study, seven rainfall stations located in and around the Nambiyar watershed were selected for analysing the rainfall trend of the study area. The daily rainfall data for the period of 1988-2018 of these stations was collected from Directorate of Economics and Statistics Department, Chennai, tabulated and calculated the mean monthly, seasonal and annual rainfall. The outcome of the data was mapped using Spline interpolation method in the GIS software in order to analyse the spatial distribution of rainfall. Further non-parametric tests like Mann-Kendall test and Sen's slope estimator were used to test significance and magnitude of rainfall trend. These tests were carried out using XLSTAT 2015 software. Spline is an interpolation technique which fits mathematical function of specified number of nearest input points while passing through the sample points and hence results in smooth surface. This technique is

useful to predict highs and lows in the data and hence best method for representing smoothly varying phenomena such as temperature and rainfall.

Mann-Kendall Test

The Mann-Kendall test is a notable test among the non-parametric tests widely used to analyse the trend of a time series phenomenon (Mann, 1945; Jeremy, 1987; Das et al.2019). This test is useful for analysing the trend of time series data especially when the sample size is small. The test statistic(S) of the series x_1,x_2, x_3…., and x_n are calculated using equation:

$$S = \sum_{k=1}^{n-1} : \sum_{j=k+1}^{n} \text{sign}(xj - xk) \quad (1)$$

Where n is the quantity of data points, sign signifies signum work x_j and x_k represents data points of time j and k.

$$\text{Sign}\left(x_{i-x_k}\right) = \begin{cases} +1 \text{ if } \left(x_i - x_k\right) > 0 \\ 0 \text{ if } \left(x_{i-x_k}\right) = 0 \\ -1 \text{ if } \left(x_{i-x_k}\right) < 0 \end{cases} \quad (2)$$

The variance of S, VAR(S) is computed by the following equation:

$$VAR(S) = \frac{1}{18}\left\{n(n-1)(2n+5) - \sum_{p=1}^{g} t_p\,(t_p-1)\,(2t_p+5)\right\} \quad (3)$$

Where, 'g' denotes the quantity of tied group's number which is a set of sample data with similar value and t_p denotes the extend of p^{th} tie number.

The estimation of (S) and VAR(S) are used to estimate process the standardized test measurement Z as:

$$Z = \begin{cases} \dfrac{(S-1)}{\sqrt{\text{Var}(S)}}, & \text{if } S > 0 \\ 0, & \text{if } S = 0 \\ \dfrac{(S+1)}{\sqrt{\text{Var}(S)}}, & \text{if } S < 0 \end{cases} \quad (4)$$

Positive and negative Z value indicates increasing and decreasing trends. The test contains two hypotheses null (H_0) hypothesis meaning 'no trend' in series and alternative (H_1) hypothesis indicating an upward or downward trend. Null hypothesis is rejected if the |Z| value is greater than $Z\alpha/2$ (at α=0.001, α=0.01 and α=0.05 respective significance level) (Mann, 1945; Das et al.2019). In the present study the null hypothesis is tested at 95% confidence level.

Sen's Slope Estimator

Sen's slope is another non-parametric test which gives quantity of slope (magnitude) in a time-series data. (Sen, 1 968; Pal et al.2017; Das et al.2019). To find the slope estimate (Q), the slopes of N pairs of data are computed using the following formula:

$Qi = \frac{xk - xj}{k - j}$, i=1,2,……..N, k>j (5)

Where, x_k and x_j are the values of data at time k_j and k_i is the median slope respectively.

In the present study, test statistic in both tests is significant at 0.05 level.

Results and Discussion

Distribution of Mean Annual Rainfall

The mean annual rainfall was computed by taking the sum of twelve-month long term monthly mean. The average annual precipitation of the Nambiyar watershed is 1027 mm and it varied from 639.6mm to 1881.3mm. The relief of a region was one of the most important factors which influenced the rainfall distribution. The two stations Balamore and Keeiparai located in the northwestern part of the watershed which lies in the Western Ghats receives highest annual rainfall throughout the year. Out of the four stations, Northeast Monsoon season had significant influence in the rainfall distribution all over the watershed, where it contributed about 47 per cent of the total rainfall received in that area. Southwest monsoon constituted around 30 per cent of the total rainfall received in the watershed. During summer through convectional rainfall, the watershed received rain and its contribution was about18.23 per cent and the winter season comes with a low percentage share which is 5 per cent of total annual rainfall. The Figure 2 illustrated the distribution of average rainfall in the watershed.

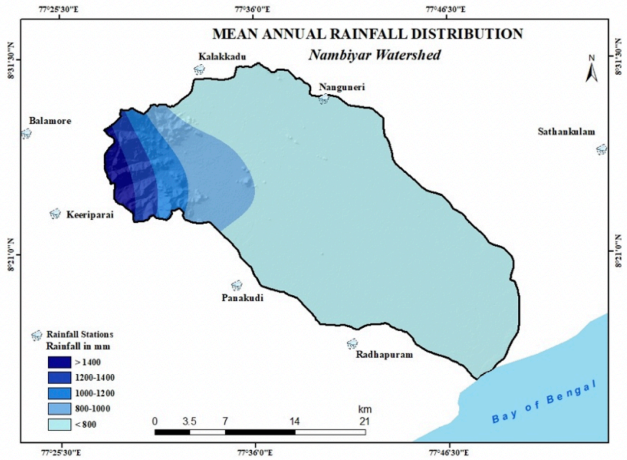

Fig. 2. Mean Annual Rainfall Distribution in Nambiyar Watershed

The following Table 1 showed the results of Mann-Kendall and Sen's slope estimated for mean annual rainfall of different stations in Nambiyar Watershed.

The calculated Z values for the annual rainfall among different stations indicate there is no significant trend in

Table 1. Mann-Kendall (Z) & Sen's Slope (Q) values for Annual Rainfall

Sl.No	Rainfall Stations	Mean Annual Rainfall in mm	S	VAR (S)	Kendall Tau	p Value (Two tailed)	alpha	Test Interpretation	Sen's slope (Q)
1	Balamore	1881.26	59.00	0.00	0.13	0.32	0.05	Accept H_0 (NS)	7.93
2	Kalakkadu	680.70	83.00	3453.00	0.18	0.16	0.05	Accept H_0 (NS)	7.07
3	Keeriparai	1874.21	-37.00	0.00	-0.08	0.54	0.05	Accept H_0 (NS)	-4.10
4	Nanguneri	693.12	-47.00	0.00	-0.10	0.44	0.05	Accept H_0 (NS)	-4.11
5	Panakudi	743.98	56.00	3417.33	0.12	0.35	0.05	Accept H_0 (NS)	11.70
6	Radhapuram	674.82	-45.00	0.00	-0.10	0.46	0.05	Accept H_0 (NS)	-4.38
7	Sathankulam	639.56	-13.00	0.00	-0.03	0.84	0.05	Accept H_0 (NS)	-1.91

S-Significant Trend NS-Non Significant

temporal precipitation in the study area. The Sen's slope estimate gives the magnitude of trend which is useful for identifying the linear relationships. Considering the Q values it is evident that four stations Keeriparai (-4.10 mm), Nanguneri (-4.11 mm), Radhapuram (-4.38 mm), and Sathankulam (-1.91 mm) shows negative Q values which implies a negative trend in the quantity of rainfall received. Kendall Tau value gives the correlation strength between the ranks of two variables considering the positive and negative values. These same stations exhibit a negative Kendall tau value indicating a negative trend between year and amount of rainfall received in these stations. The Figure 3 represents the Z and Q values calculated for all rainfall stations in Nambiyar Watershed. The Table 2 and Figure 3 shows the graphical representation of annual rainfall trend in Nambiyar Watershed.

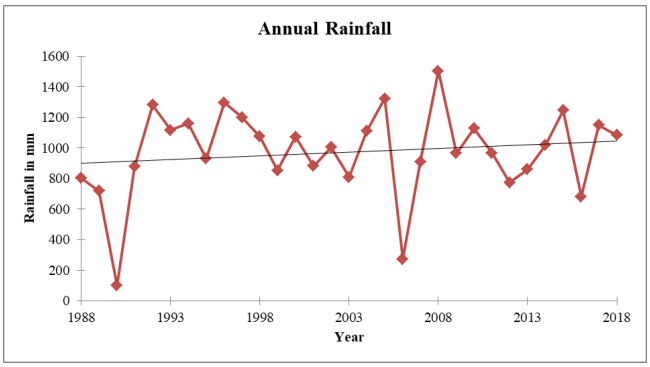

Fig. 3. Annual rainfall trend of different stations

Seasonal Rainfall Distribution

In the present study it is evident that the winter season contributed (5 per cent) less amount of rainfall (47 mm) to the annual precipitation. In this season rainfall varied from 36.70 mm to 56.20 mm recorded in Panakudi and Nanguneri stations, respectively. Winter rainfall showed a decreasing

Table 2. Mean Annual rainfall in Nambiyar watershed

Year	TOTAL		
1988	803.84	**2004**	1111.01
1989	719.41	**2005**	1322.29
1990	100.31	**2006**	273.23
1991	877.67	**2007**	911.26
1992	1281.93	**2008**	1503.10
1993	1117.30	**2009**	964.46
1994	1160.73	**2010**	1127.46
1995	930.80	**2011**	966.80
1996	1297.31	**2012**	773.73
1997	1199.37	**2013**	860.30
1998	1075.90	**2014**	1020.76
1999	853.89	**2015**	1245.26
2000	1073.93	**2016**	681.73
2001	880.79	**2017**	1149.27
2002	1004.37	**2018**	1084.91
2003	808.96		

spatially from from north to southern portion of study area.

The mean rainfall of the summer season constituted about 187.14 mm (18.23 per cent) of the total rainfall of the area. The amount of summer rainfall varied from 109.72 mm at Sathankulam to 369.79 mm at Keeriparai. The spatial pattern of summer rainfall showed a decreasing trend from Western Ghats in western portion towards the coastal region in the eastern part of the watershed.

The southern part of the country received more amount of rainfall from the Arabian Sea branch of the southwest monsoon. Even though major portion of Tamil Nadu state received more rainfall during the northeast monsoon, some districts in the western and southern part of the states were more influenced by the southwest monsoon. The western part of the Nambiyar watershed had received more rainfall from southwest monsoon which constitutes around 30.22 per cent (310.31 mm) of total rainfall.

The northeast monsoon also called as retreating monsoon starts form October and last till December. Most of the interior parts of Tamil Nadu received heavy rainfall from the northeast monsoon. The Nambiyar watershed also received abundant rainfall from the northeast monsoon which varies from 647.99 mm in Keeriparai to 393.31 at Radhapuram. The watershed receives more rainfall from northeast season i.e is 47 per cent (482.57 mm) of total rainfall. The Figure 4 illustrates the distribution of average rainfall in the watershed during different seasons.

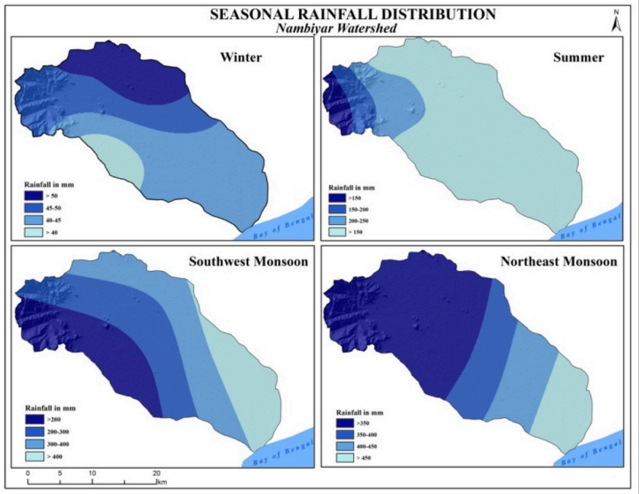

Fig. 4. Distribution of Seasonal Rainfall in Nambiyar Watershed

The Mann Kendall and Sen's slope was estimated to analyse the signigicance and magnitude of trend for each season in all stations. In general, all the seasons does not exhibit a significant trend in the rainfall over all stations.However, as an exception Winter, Summer and Southwest monsoon shows an significant incerasing trend in Kalakkadu station.It is evident that magnitude of winter rain is incerases with time except in Sathankulam station where it declines at a rate of -0.28 mm (Sen's slope Q Value) annually.Similarly, quantity of summer rain decreases at a rate of -0.67 mm, and -0.49 mm at Nanguneri and Radhapuram respectively.

The quantity of southwest monsoon exhibits a declining trend in Keeriaparai(-8.98 mm),Nanguneri (-1 mm), Sathkulam (-1.60 mm) stations. Eventhough northeast monsoon does indicate any significant trend all the stations have upward magnitude of rainfall except for Radhapuram station where it is decreasing at a rate of -1.72 mm (Sen's slope Q value). The estimated Mann Kendall statistic, Kendall Tau and Sen's slope value of different seasons are given in the Table 3 and represented in the Figure 5.

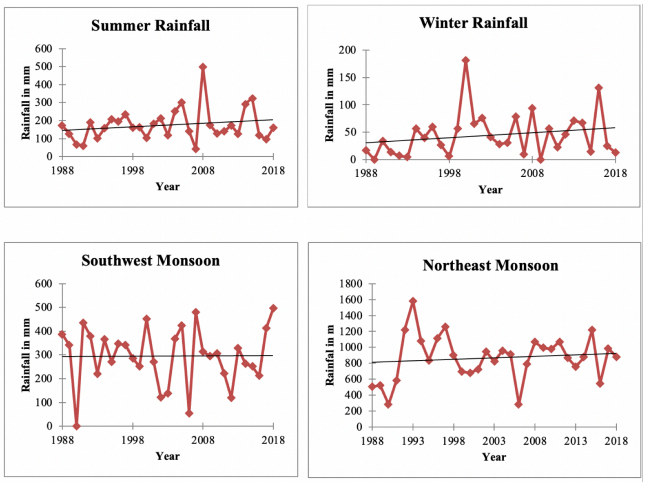

Fig. 5. Seasonal rainfall trend of different stations

Distribution of Monthly Rainfall

The months of January, February and March received average rainfall of less than 50 mm which constitutes 5 per cent of the total annual rainfall. During the month of May the watershed received greater amount of rainfall from convectional rains i.e an average of 75 mm which is 7.36 per cent of the total annual rainfall. The June month recorded highest rainfall among southwest monsoon months i.e an average of 100.39 mm and constitutes about 9.78 per cent of total rainfall. The monthly rainfall of June varies form 8.46 mm in Sathankulam to 174.84 mm in Balamore. Since the watershed receives more rainfall in northeast monsoon November month records highest average rainfall of about 217.52 mm which is 21.18 per cent of total rainfall. During the November month rainfall varies from 196.74 mm in Sathankulam to 248.68 mm in Keeriparai. The spatial distributions of rainfall in watershed during twelve months are shown in Figure 6.

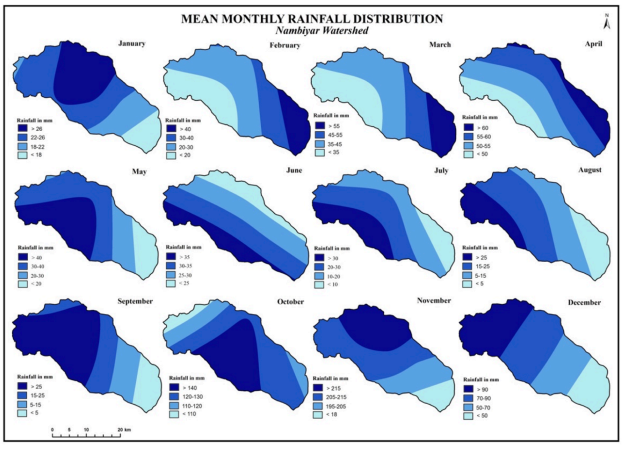

Fig. 6. Distribution of Monthly Rainfall in Nambiyar Watershed

Table 3. Mann-Kendall (Z) & Sen's Slope (Q) values for Seasonal Rainfall

Sl.No	Station	Test Statistic& Result	Winter	Summer	Southwest Monsoon	Northeast Monsoon
1	Balamore	Kendall Tau	0.171	0.170	0.028	0.157
		MK (Z)	0.18	0.18	0.84	0.22
		Result	NS	NS	NS	NS
		Sen's Slope(Q)	0.65	2.73	1.91	10.72
2	Kalakkadu	Kendall Tau	0.325	0.258	0.257	0.141
		MK (Z)	0.01	0.04	0.05	0.28
		Result	S	S	S	NS
		Sen's Slope(Q)	1.31	3.85	2.29	5.03
3	Keeriparai	Kendall Tau	0.056	0.209	-0.187	0.103
		MK (Z)	0.67	0.10	0.14	0.42
		Result	NS	NS	NS	NS
		Sen's Slope(Q)	0.30	4.14	-8.98	13.62
4	Nanguneri	Kendall Tau	0.145	-0.032	-0.129	0.017
		MK (Z)	0.27	0.81	0.32	0.91
		Result	NS	NS	NS	NS
		Sen's Slope(Q)	1.00	-0.67	-1.00	0.25
5	Panakudi	Kendall Tau	0.182	0.092	0.204	0.096
		MK (Z)	0.19	0.49	0.12	0.47
		Result	NS	NS	NS	NS
		Sen's Slope(Q)	0.00	0.13	3.16	1.59
6	Radhapuram	Kendall Tau	0.183	-0.050	0.032	-0.056
		MK (Z)	0.16	0.71	0.81	0.67
		Result	NS	NS	NS	NS
		Sen's Slope(Q)	1.00	-0.49	0.24	-1.72
7	Sathankulam	Kendall Tau	-0.095	0.002	-0.193	0.000
		MK (Z)	0.47	1.00	0.13	1.00
		Result	NS	NS	NS	NS
		Sen's Slope(Q)	-0.28	0.07	-1.60	0.00

S-Significant Trend NS-Non Significant

The Mann Kendall test and Sen's slope estimated for different months of all stations reveals that particular months exhibit a significant upward trend of temporal rainfall distribution in the Nambiyar Watershed.

The Mann Kendall test and Sen's slope estimated for different months of all stations reveals that particular months exhibit a significant upward trend of temporal rainfall distribution in the Nambiyar Watershed. The rainfall recorded in March and December months shows an increasing significant trend with a magnitude of 1.25mm (Q Value) and 1.64mm (Q Value) respectively at Balamore station. The temporal pattern of rainfall received in month of January and March exhibits a significant upward trend at the rate of 0.24mm and 0.59mm (Q Values) at Kalakkadu station. Even though rest of the months does not exhibit significant trend magnitude of the rainfall shows an upward trend. The rainfall received during the month of May, July and December reveals the existence of significant increasing trend at Keeriparai station. The Q values estimated for the months of April (-1.40mm), June (-1.40mm), (-5.01mm), September (-2.82mm) and October (-4.86mm) indicate a fall in the quantity of rainfall in this station. At station Nanguneri, temporal rainfall does not reveal any significant trend. The Sen's slope estimation of this station indicates the fact that for most of the months such January, February, March, May and August magnitude of rainfall is constant. Also a decreasing trend in magnitude is visible in months of April (-0.77mm), June (-0.07mm), July (-0.25mm) and October (-1.06mm). The rainfall trend is positively significant only for the month of December in Panakudi. During other months magnitude of rainfall is either constant or shows a upward trend. The rainfall received at Radhapuram is highly randomized where no months show any presence of trend.

Table 4. Mann-Kendall (Z) & Sen's Slope (Q) values for Monthly Rainfall

Stations	Test Statistic& Results	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Balamore	Kendall Tau	0.12	0.11	0.33	0.20	0.21	0.02	-0.15	0.09	0.05	0.01	0.14	0.26
	MK (Z)	0.40	0.43	0.01	0.10	0.10	0.84	0.22	0.46	0.69	0.97	0.25	0.04
	Result	NS	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	S
	Sen's Slope(Q)	0.00	0.00	1.25	-1.72	3.35	1.20	-3.30	1.56	0.95	0.00	3.17	1.64
Kalakkadu	Kendall Tau	0.28	0.20	0.40	0.18	0.04	0.13	0.17	0.24	0.17	0.08	0.18	0.23
	MK (Z)	0.03	0.13	0.00	0.16	0.73	0.30	0.19	0.06	0.18	0.52	0.14	0.06
	Result	S	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Sen's Slope(Q)	0.24	0.07	0.59	1.12	0.00	0.11	0.21	0.20	0.10	1.02	4.52	2.91
Keeriparai	Kendall Tau	0.00	0.10	0.17	-0.13	0.26	-0.05	-0.24	0.08	-0.11	-0.15	0.13	0.28
	MK (Z)	1.00	0.41	0.17	0.29	0.03	0.69	0.05	0.49	0.36	0.24	0.31	0.02
	Result	NS	NS	NS	NS	S	NS	S	NS	NS	NS	NS	S
	Sen's Slope(Q)	0.00	0.25	1.23	-1.40	4.60	-1.40	-5.01	1.58	-2.82	-4.86	2.30	1.44
Nanguneri	Kendall Tau	0.10	0.05	-0.01	-0.13	0.04	-0.11	-0.21	0.04	-0.14	-0.07	0.04	0.13
	MK (Z)	0.44	0.68	0.95	0.31	0.75	0.39	0.11	0.72	0.29	0.58	0.74	0.30
	Result	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Sen's Slope(Q)	0.00	0.00	0.00	-0.77	0.00	-0.07	-0.25	0.00	-0.39	-1.06	1.21	0.80
Panakudi	Kendall Tau	0.01	0.14	0.21	0.15	0.01	0.20	0.24	0.11	0.11	-0.01	0.14	0.45
	MK (Z)	0.91	0.34	0.13	0.27	0.91	0.13	0.07	0.43	0.44	0.95	0.28	0.00
	Result	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S
	Sen's Slope(Q)	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	1.86	2.23
Radhapuram	Kendall Tau	0.02	0.11	-0.02	-0.08	0.06	0.01	-0.11	0.03	0.17	-0.20	0.01	0.02
	MK (Z)	0.84	0.41	0.85	0.50	0.62	0.91	0.40	0.83	0.18	0.11	0.90	0.85
	Result	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Sen's Slope(Q)	0.00	0.00	0.00	-0.32	0.00	0.00	-0.43	0.00	0.30	-3.55	0.15	0.00
Sathankulam	Kendall Tau	-0.09	-0.02	0.05	-0.20	0.08	-0.24	-0.12	0.14	-0.29	0.11	-0.02	0.12
	MK (Z)	0.49	0.88	0.70	0.12	0.58	0.07	0.35	0.30	0.02	0.39	0.86	0.34
	Result	NS	NS	NS	NS	NS	NS	NS	NS	S	NS	NS	NS
	Sen's Slope(Q)	0.00	0.00	0.00	-0.95	0.00	-0.23	0.00	0.00	-0.72	2.31	-0.50	1.42

S-Significant Trend NS-Non Significant

The month of September exhibits significant negative trend where rainfall is decreasing at a rate of -0.72 (Q Value). Also rainfall pattern during April, May and November months exhibit downward magnitude in the quantity of rainfall. The estimated Mann Kendall statistic, Kendall Tau and Sen's slope value of different seasons are given in the following Table 4.

Conclusions

The precipitation trend analysed using different non-parametric test brings out the fact that it varied spatially and temporally throughout the watershed. The outcome of rainfall trend analysis by Mann-Kendall statistics at α= 0.05 or 95 % significance level implies that in general there is no significant trend in annual rainfall of the watershed. However, seasonal and monthly rainfall showed significant increasing and decreasing trend in different parts of the watershed. This indicated rainfall received in watershed was not reliable. The rainfall recorded in different stations also exhibited variations on the basis of different seasons and months. Monsoon rainfall was the significant contributor to total rainfall received in the watershed. Southwest monsoon is a notable contributor to the total rainfall next to northeast monsoon in the watershed and its influence is mainly visible in the western part of the watershed i.e the foothills of Western Ghats. The Rainfall during winter season is received in a negligible amount. The statistical and spatial analysis of rainfall carried out in this study implies varying nature of rainfall in the Nambiyar watershed and hence reminds the need of proper planning and management of water resources.

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