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Rainfall Trend Investigation of Hemavati Catchment, Karnataka, India

Ashwini B, Shivakumar J Nyamathi

Abstract*: *The rainfall trend investigation study supports to judge the periodic pattern of rainfall. The quantifiable evaluation of the overall impacts of different elements, for example, changes in precipitation, temperature, evapotranspiration, environmental changes encouraged by a hazardous atmospheric deviation and human activities on the streamflow is critical for territorial appraisal of water assets and its feasible management. This study focusses on to analyze the seasonal rainfall trend in Hemavati Catchment, Karnataka, India. For the present study, thirty-two years (1990-2021) of seasonal rainfall trend has been examined using the Mann-Kendall assessment and Sen's gradient estimation methods. The investigation has been carried out for the cold weather season (December-February), hot weather season (March-May), southwest monsoon season (June-September), and post–monsoon season (October–November) by the use of XLSTAT software and the study demonstrations that here is a varied trend in the catchment.

Keywords*: *Mann-Kendall test (Z), Sen's Slope factor (Q_{med}), cold weather season (CWS), hot weather season (HWS), south west monsoon season (SWMS), post–monsoon season (PMS).

I. INTRODUCTION

Rainfall is a critical climatic variable that significantly impacts various aspects of human life, agriculture, ecosystems, and water resources. The investigation of long-term trends in rainfall patterns is essential for understanding climate change, assessing hydrological risks, and making well-versed conclusions about water resource supervision and disaster preparedness [1][11]. Trend analysis of rainfall involves the examination of historical rainfall data to identify significant changes or patterns over time [2][14][15]. The hydrological sequence of a river basin is a multipart procedure influenced by environment, anthropogenic exercises and the landscape attributes of the region [3]. The Earth's climate is continually evolving, influenced by various natural processes and human activities. Climate change can lead to shifts in precipitation patterns, affecting rainfall intensity, frequency, and distribution.

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Understanding these trends are crucial for adapting to potential variations in water availability, as regions experiencing more intense and frequent rainfall may face flooding and erosion risks, while regions with declining rainfall may experience drought and water scarcity. Subsequently in the current review an attempt has been made to find rainfall patterns in the chosen study region using a non-parametric statistical method [4][12][13]. The Hemavati catchment area plays a vital role in supporting agricultural activities in the region. Water from the Hemavati River and its reservoir is utilized for irrigation purposes, adding to the state's agricultural economy. The dam water storage also helps in managing water accessibility throughout dry periods and mitigating the effects of drought. Like many other river catchments in India, the Hemavati catchment faces challenges related to water sustainability and management. Factors such as environmental change, population growth and urbanization, can impact water availability and quality in the region. Proper water resource supervision policies are essential to ensure the sustainable use of water and to address potential water-related challenges in the catchment.

II. MATERIALS AND METHODLOGY

A. Study Area and Data used

The Hemavati is a river in southern India near Karnataka and a huge feeder of the river Cauvery. For the current study, Hemavati Catchment up to M H Halli gauging station which is located in Hassan district having a latitude of 12°49'08" N and Longitude of 76°08'00" E is considered. The river takes birth in the Western Ghats at an elevation of about 1,219 meters near Ballalarayanadurga in the Chikkamagaluru region of Karnataka state, India. The Hemavathi rises in the Western Ghats and runs South-East. After a stream from the West goes along with it, it turns East, getting the Yagachi from the North. It then breezes round Holenarasipur and runs South to the Cauvery close to Yedatore. The river flows through Hassan district which is joined by its chief tributary Yagachi River which finally joins river Cauvery having a catchment area of 3013 sq. km with a perimeter of 535 km. The catchment area is delineated considering M H Halli as outlet point using Digital elevation model (DEM) downloaded from UGSG Earth Explorer. The four DEM considered for the catchment delineation are SRTM1N13E075V3, SRTM1N13E076V3, SRTM1N12E075V3 and SRTM1N12E076V3 dated 23-09-2014 using ArcMap. The study area is lies between 12°40'00" N to 13°20'00" N and 75°30'00" E to 76°10'00" E.

The location map of study region with rain gauge stations is represented in the Fig. 1. The observed rainfall readings used for this study is collected from district rainfall statistical department for 32 years (1990-2021). The missing rainfall data is analyzed using interpolation method and then examined the rainfall trend for the considered period.

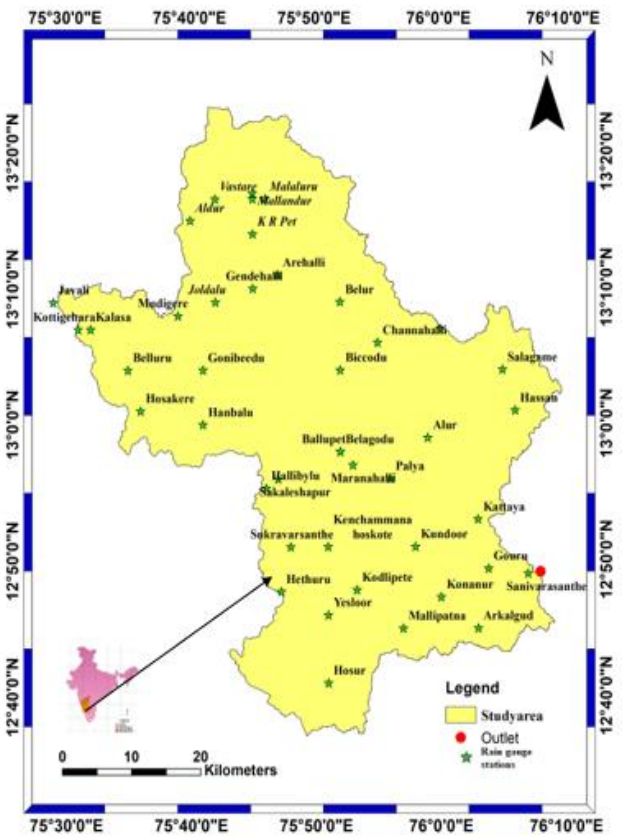

Fig. 1. Location Map of Study Region with Rain Gauge Stations

There are forty three rain gauge stations which covers the study region, they are Alduru, Chikkamagaluru, Malaluru, Mallandur, Vastare, Joldalu, K R Pete (Chikkamagaluru taluk); Gonibeedu, Kottigehara, Kalasa, Mudigere, Javali, Belluru, Hosakere (Mudigere taluk); Aluru, Kenchammana hoskote, Palya, Channahalli, Kundoor (Alur taluk); Arkalgud, Konanur, Mallipatna (Arkalgud taluk); Arehalli, Beluru, Biccodu, Gendehalli, Hagare, (Belur taluk) ; Goruru, Hassan, Kattaya, Salagame (Hassan taluk); Ballupete, Hanabalu, Maranahalli, Sukravarsanthe, Yesloor, Sakaleshapur, Hosur, Hallibailu, Hethuru, Belagodu (Sakaleshpur taluk); Kodlipete, Sanivarasanthe (Somvarpete taluk).

B. Methodology

The Rainfall pattern study were performed with the non-parametric Mann- Kendall test (Mann, 1945; Kendall, 1975) [5]. The Mann-Kendall test was useful for the detection of monotonic upward or downward pattern and relies upon the relationship between the ranks of a time series and their time order [5]. The test measurement relies just upon the ranks of the observations, rather than their real values, ensuing in a distribution-free test statistic [6], [7]. The numerical significance of patterns was characterized by means of a significance level of α = 0.05 for Mann-Kendall's p-value. When a linear pattern is available in a time series, then the correct slope (change per unit time) is assessed by means of non-parametric technique (Sen's Slope) established by Sen (1963) [3]. The mathematical procedure for the Mann Kendall assessment is presented as follows: The Mann-Kendall S Statistic is calculated as follows:

$$S = \sum_{i=0}^{n=1} \sum_{j=k+1}^{n} \operatorname{sgn}\left(x_j - x_i\right) \qquad (1)$$

Where, n is the number quantity of data points, χ_i and χ_j are the data values in time series i and j (j>i) and sgn (χ_i-χ_j) is the sign function calculated using the equation [5]

$$\operatorname{sgn}\left(x_j - x_i\right) = \begin{cases} +1 & \text{if} \quad x_j - x_i > 0 \\ 0 & \text{if} \quad x_j - x_i = 0 \\ -1 & \text{if} \quad x_j - x_i < 0 \end{cases} \qquad (2)$$

A positive or negative value of S specifies an upward or downward pattern respectively. If number of statistical values is 10 or further, then the variance is estimated using the below equation.

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \qquad (3)$$

Where, n is the numeral of statistical points and x_i and χ_j are two data subsets of time series i and j (j, i = 1,2, 3…., n-1 and j = i+1, i+2, i+3, …, n, j > i respectively. The sgn(χ_j-χ_i) is a sign function. Data are assessed in an orderly manner and every data is associated with all succeeding data values. The statistic S is incremented by 1, if a data value is higher than its earlier data value. On the other side S is decremented by 1, if the statistical value is lower than its earlier data value. The standard normal distribution (Z – statistics) is computed using equation.

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

Statistically the significance of trend is evaluated by means of Z value. An optimistic value of Z shows increasing pattern while the pessimistic value indicates decreasing pattern in the series of data. An optimistic value of Z signifies the positive trend, while the pessimistic values of Z signify the negative trend. The tests are done at a specific significance level. When, |Z| >Z_1-a/2, the null hypothesis is excluded and a significant pattern occurs in the time series. In the present study, a significance level of 5% is used, i.e., α = 0.05. At 5% significance level, the null hypothesis of no pattern is rejected if |Z|>1.96.

$$T_i = \left(\frac{x_j - x_k}{j-k}\right) \quad \text{for} \quad i=1,2,3......n \qquad (5)$$

Where x_j and x_k are the data values at periods j and k (j>k) respectively. The median of these N values of T_i is considered as Sen's estimator of slope, which is given as,

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$$Q_{med} = \begin{cases} T_{\frac{n+1}{2}} & \text{for } n \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{n}{2}} + T_{\frac{n+2}{2}}\right) & \text{for n is even} \end{cases} \qquad (6)$$

Sen's estimator is determined utilizing the above equation liable upon value of n is either odd or even and afterward is processed by means of 100 (1 – α) % confidence interval using non-parametric test depending upon normal distribution. [8]. A optimistic value shows increasing pattern while pessimistic value of denotes decreasing pattern of time series data [5]. Qmed sign replicates data tendency reflection, whereas its value shows the gradient of the trend. Qmed with an optimistic value specifies an upward or increasing pattern and a pessimistic value of Qmed signifies a downward or declining pattern in the time series. [9], [5].

III. RESULTS AND DISCUSSIONS

A. Results

From the observed investigation of rainfall data from 1990 to 2021 it is noted that the highest yearly rainfall of 7887.70 mm was received during the year 2007 (Hosakere) and the lowermost yearly rainfall of 296.20 mm was received during the year 2003 (Kattaya), spatial distribution of rainfall over study region is denoted in fig. 2. Further spatial rainfall distribution from 1990-2021 is denoted in Box and Whisker Plot for CWS, HWS, SWMS and PMS in fig. 3 and fig. 4 respectively.

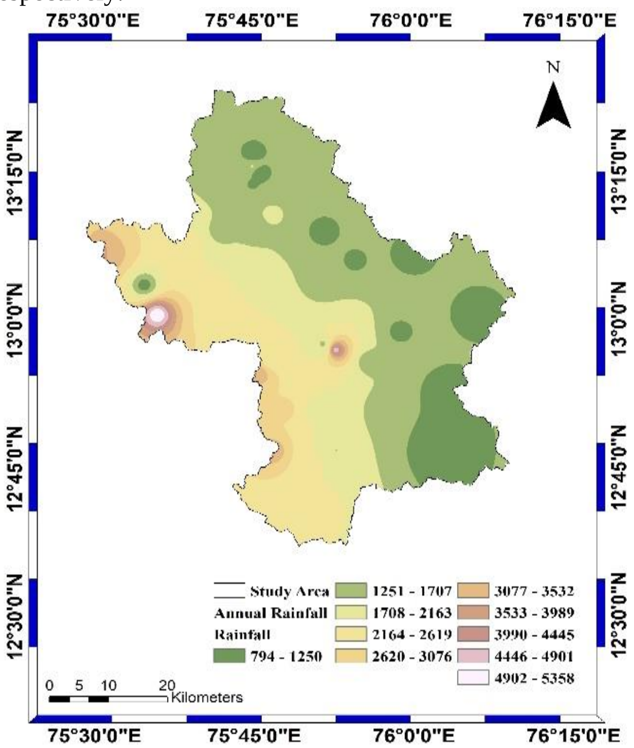

Fig. 2. Spatial Distribution of Rainfall

The box plot for rainfall in the catchment reveals important insights into the variability and extreme values related with these variables. The length of the box represents the interquartile range (IQR), which spans from the 25th percentile (lower quartile) to the 75th percentile (upper quartile). A larger IQR indicates greater variability in the data, while a smaller IQR suggests more consistent values. Additionally, outliers, represented by individual points beyond the whiskers of the box plot, indicate extreme values or anomalies in the dataset. In the framework of the study area considered, the box plots (Fig.3 and fig 4) clearly demonstrate that during that more quantity of rainfall is received in the southwest monsoon season when compared to any other season. Moreover, the occurrence of high outlier values indicates the occurrence of heavy rainfall. These findings highlight the importance of understanding and monitoring the periodic rainfall variations in the catchment.

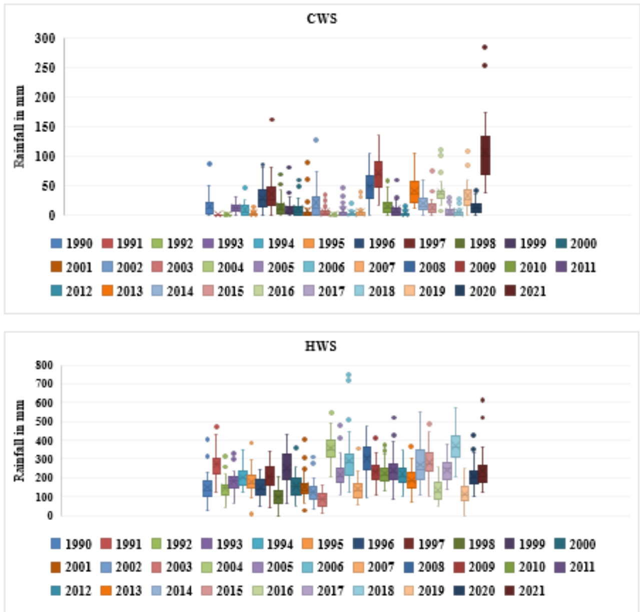

Fig. 3 Box and Whisker Plot for CWS and HWS Rainfall Distribution from 1990-2021

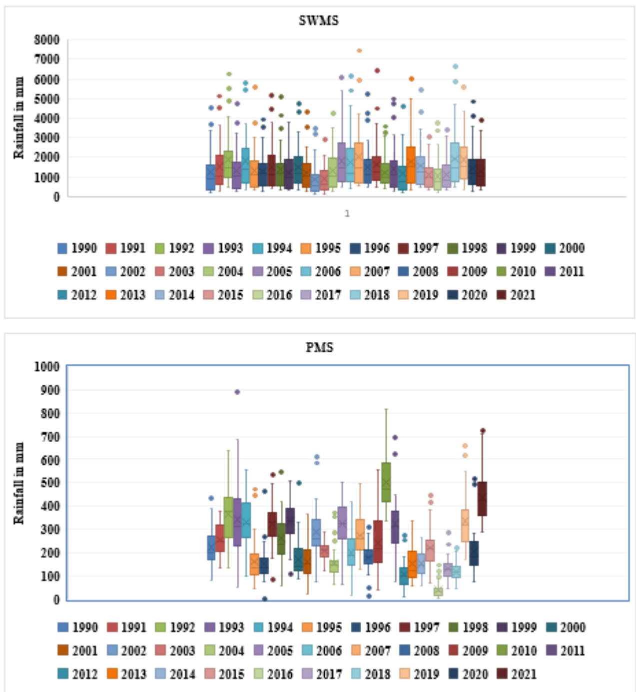

Fig. 4 Box and Whisker Plot for SWM and PMS Rainfall Distribution from 1990-2021

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Table-I: Summary of Results of Various Rain Gauge Station

Sl No	Rain Gauge Station	Test	CWS	HWS	SWMS	PMS
1	Kodlipete	Z	0.15	0.07	0.11	-0.07
		Q_{med}	0	0.78	3.99	-0.67
2	Shanivarasanthe	Z	0.05	0.09	-0.04	0.03
		Q_{med}	0	0.44	-1.12	0.33
3	Alur	Z	0.22	0.16	0.04	-0.19
		Q_{med}	0.22	2.54	2.29	-3.88
4	Kenchammana Hosakote	Z	0.08	0.04	-0.19	-0.26
		Q_{med}	0	0.62	-12.44	-5.97
5	Palya	Z	0.18	0.13	-0.3	-0.17
		Q_{med}	0.03	1.75	-14.47	-4.37
6	Channahalli	Z	0.39	0.3	0.11	-0.07
		Q_{med}	0.03	5.7	5.1	-1.4
7	Kunduru	Z	0.23	0.23	0.02	-0.15
		Q_{med}	0.29	2.99	1.17	-2.76
8	Arakalagudu	Z	0.08	-0.07	-0.01	-0.08
		Q_{med}	0	-1.22	-0.2	-1.17
9	Konanur	Z	0.13	0.13	-0.08	-0.21
		Q_{med}	0.19	1.13	-1.64	-4.13
10	Mallipatna	Z	0.19	0.19	0.04	-0.15
		Q_{med}	0.26	2.58	1.41	-2.5
11	Arehally	Z	0.19	0.12	-0.04	-0.05
		Q_{med}	0	1.48	-3.06	-2.08
12	Beluru	Z	0.31	0.22	0.03	-0.23
		Q_{med}	0.5	3.09	0.66	-4.84
13	Biccodu	Z	0.25	0.24	-0.04	-0.14
		Q_{med}	0	3.58	-1.58	-3.24
14	Gendehally	Z	0.34	0.21	0	-0.25
		Q_{med}	0.49	3.04	-0.04	-5.28
15	Hagare	Z	0.28	0.05	0.07	-0.07
		Q_{med}	0.46	1	1.6	-0.91
16	Goruru	Z	0.17	0.19	0.3	-0.12
		Q_{med}	0.18	2.63	7.75	-2.1
17	Hassan	Z	0.29	0.17	0.14	-0.16
		Q_{med}	0.54	2.29	4.45	-2.92
18	Kattaya	Z	0.2	0.26	0.31	0.08
		Q_{med}	0.08	3.39	8.22	1.49
19	Salagame	Z	0.19	0.12	0.1	-0.15
		Q_{med}	0	1.39	3.09	-2.42
20	Ballupete	Z	0.13	0.13	-0.02	-0.18
		Q_{med}	0.05	2.41	-1.35	-3.93
21	Hanbalu	Z	0.14	0.1	-0.18	-0.02
		Q_{med}	0	1.58	-10.75	-0.63
22	Maranahally	Z	0.24	-0.02	-0.19	0.04
		Q_{med}	0	-0.44	-26.01	0.85
23	Sukravarsanthe	Z	0.24	0.17	-0.08	-0.14
		Q_{med}	0	2.57	-7.05	-2.43
24	Yesluru	Z	0.01	0.18	0.22	-0.04
		Q_{med}	0	1.8	15.47	-0.61
25	Sakaleshapura	Z	0.3	0	0.04	-0.21
		Q_{med}	0.45	0.11	2.25	-3.93
26	Hosuru	Z	0.07	0.09	-0.05	-0.13
		Q_{med}	0.07	0.65	-2.62	-2.87
27	Belagodu	Z	0.21	0.21	0.08	-0.13
		Q_{med}	0	2.83	5.83	-2.98
28	Hallibailu	Z	0.19	0.26	0.1	-0.13
		Q_{med}	0.19	3.32	7.74	-3.17

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29	Hethuru	Z	0.15	0.22	-0.01	-0.24
		Q_{med}	0.28	2.63	-1.32	-3.88
30	Alduru	Z	0.26	0.15	0.11	0.05
		Q_{med}	0.37	2.88	6.38	0.69
31	Chikkamagaluru	Z	0.07	0.2	0	-0.17
		Q_{med}	0	2.18	0.14	-3.53
32	Malaluru	Z	0.15	0.14	0.27	-0.1
		Q_{med}	0	1.79	5.72	-1.74
33	Malandur	Z	0.22	0.09	0.05	-0.22
		Q_{med}	0.23	1.26	2.08	-4.44
34	Vastare	Z	0.17	0.19	-0.09	-0.18
		Q_{med}	0.17	2.7	-3.41	-2.28
35	Joldalu	Z	0.12	0.12	0.09	-0.29
		Q_{med}	0.24	2.23	5.43	-6.45
36	K.R.Pete	Z	0.25	-0.17	-0.23	-0.25
		Q_{med}	0.14	-1.85	-8.31	-4.55
37	Gonibeedu	Z	0.21	-0.02	-0.05	-0.17
		Q_{med}	0.17	-0.55	-4.69	-2.67
38	Kottigehara	Z	0.38	0.21	0.07	0.05
		Q_{med}	0.27	2.92	8.73	2.1
39	Kalasa	Z	0.22	0.19	-0.06	-0.06
		Q_{med}	0.28	4	-7.11	-1.58
40	Mudigere	Z	0.24	0.25	0.13	-0.05
		Q_{med}	0.34	5.08	11.12	-0.77
41	Javali	Z	0.21	0.15	0.06	-0.14
		Q_{med}	0.14	2.54	5.43	-3.78
42	Bellur	Z	0.28	0.21	-0.02	-0.23
		Q_{med}	0.47	2.95	-0.21	-4.85
43	Hosakere	Z	0.27	-0.05	0.02	0.05
		Q_{med}	0.46	-1.17	5.02	1.09

Many authors have attempted to find the trend pattern in rainfall on both national and provincial scales. Maximum of these deal with the study of annual and seasonal sequences of rainfall for few individual stations or clusters of stations. A few past analysis associated to changes in rainfall over India have summarized that here is no clear trend in average annual rainfall over India. [10]. Here the summary of results of selected study region for Z and Q_{med} for CWS, HWS, SWMS and PMS are discussed in Table-I. The overhead table clearly specifies that positive value of Z indicates increasing in rainfall trend and negative values shows decreasing in rainfall trend and zero specifies there is no rainfall trend in the study region considered for analysis. As mentioned earlier Mann-Kendall and Sen's Slope estimators are non-parametric statistical methods utilized to detect the patterns in the time series data. Mann-Kendal test is used to distinguish the presence of trend in a time series, while Sen's gradient estimator is used to estimate the magnitude of the trend. In this study to examine the rainfall trend XLSTAT is used and the summary of the result obtained is consolidated for the Cold weather season (December-February), hot weather season (March- May), pre-monsoon season (June-September) and Post monsoon season (October-November) as addressed in Table-I. Further the spatial distribution of Kendall's Tau (Z) is represented in the figure from fig. 5 to fig.8 and spatial distribution of Sen's slope (Q_{med}) is represented in figure form fig.9 to fig.12 respectively. The review's discoveries might assist leaders and water chiefs with giving more manageable techniques and strategies for overseeing water assets.

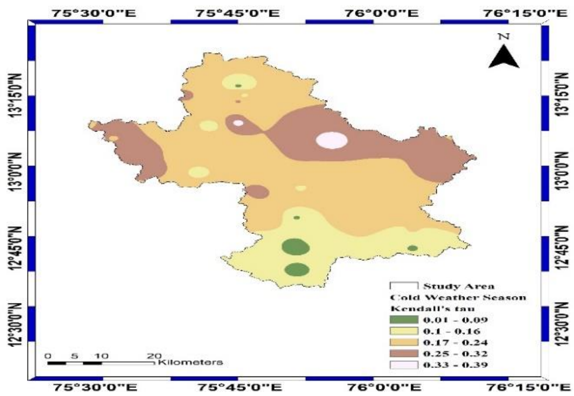

Fig. 5. Spatial Distribution of Kendall's Tau for CWS, from 1990-2021

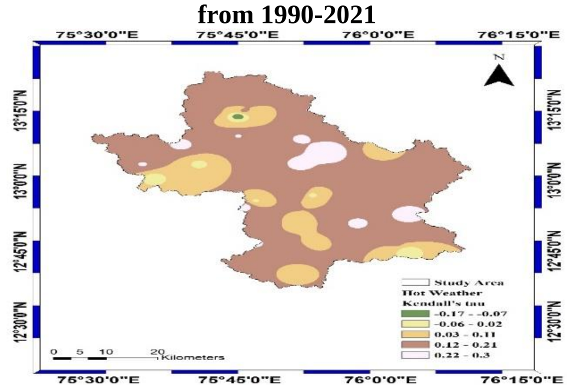

Fig. 6. Spatial Distribution of Kendall's Tau for HWS, from 1990-2021

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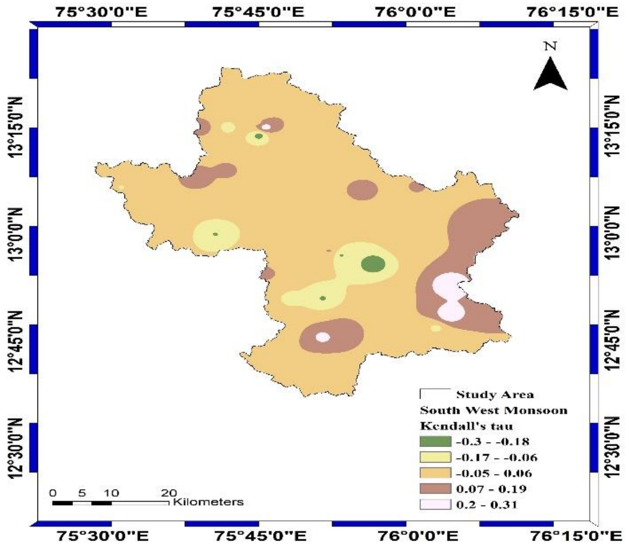

Fig. 7. Spatial Distribution of Kendall's tau for PMS, from 1990-2021

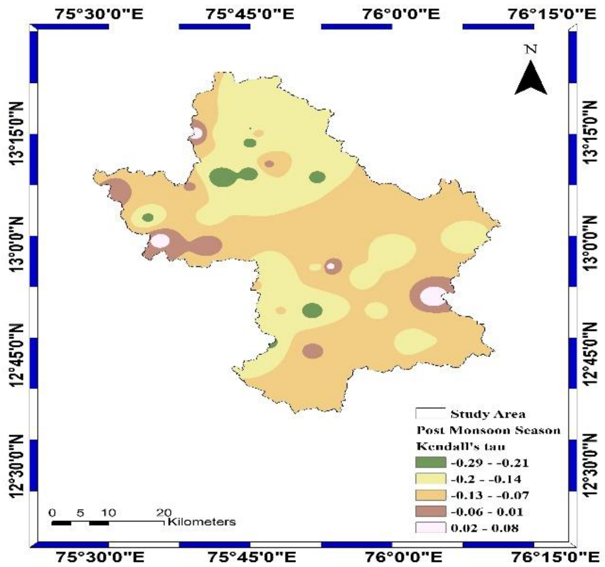

Fig. 8. Spatial Distribution of Kendall's Tau for PMS From 1990-2021

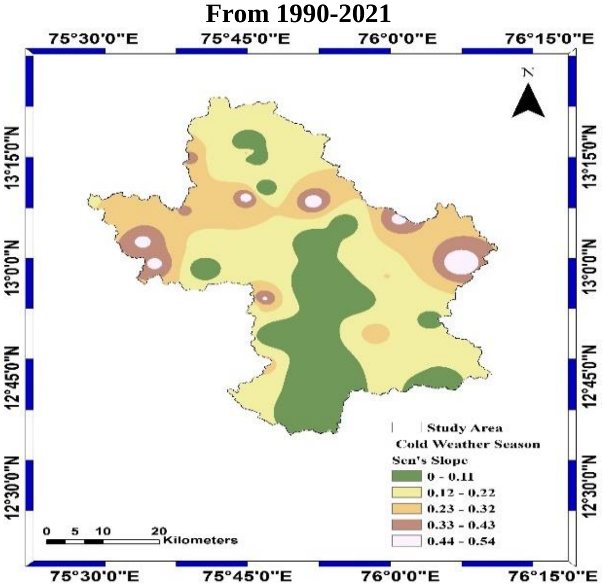

Fig. 9. Spatial Distribution of Sen's Slope for SWMS and CWS from 1990-2021

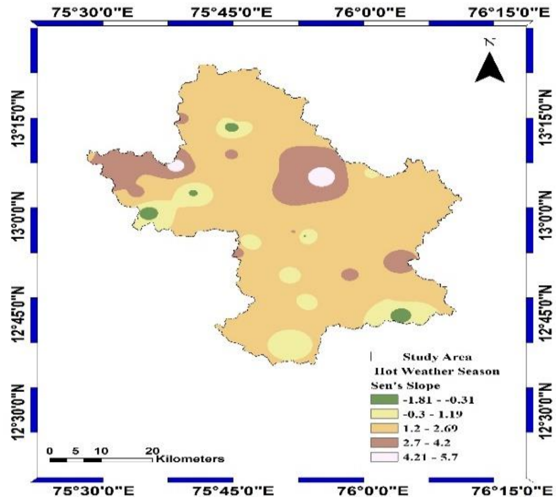

Fig. 10. Spatial Distribution of Sen's Slope for HWS from 1990-2021

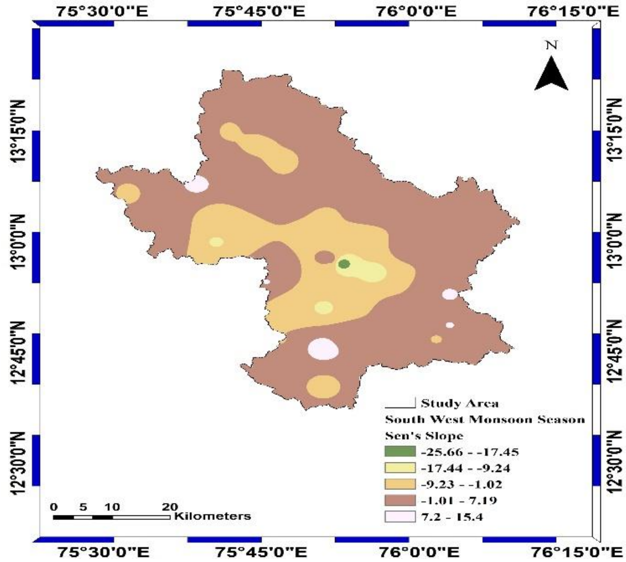

Fig. 11. Spatial Distribution of Sen's Slope for SWMS from 1990-2021

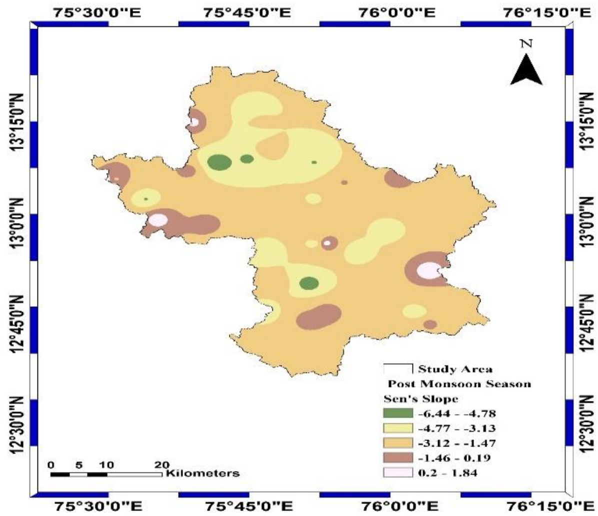

Fig. 12. Spatial Distribution of Sen's Slope for PMS from 1990-2021

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B. Discussions

a. The Cold weather season study shows non-significant positive trend in Kodlipete, Sanivarasanthe, Alur, Kenchammana Hosakote, Palya, Channahalli, Kundur, Arkalgudu, Konanur, Mallipatna, Arehally, Belur, Biccodu, Gendehally, Hagare, Gorur, Hassan, Kattaya, Salagame, Ballupet, Hanbalu, Maranahally Sukravarsanthe, Yelsuru, Sakaleshapura, Hosuru, Belagodu, Hallibailu, Hethuru, Alduru, Chikkamagaluru, Malaluru, Malanduru, Vastare, Joldalu, Kottigehara, Kalasa, Mudigere, Javali and Belluru.

b. The Hot weather season rainfall trend thought the period of study shows non-significant increasing trend in Kodlipete, Sanivarasanthe, Aluru, Kenchammana Hosakote, Palya, Channahalli, Kunduru, Konanuru, Mallipatna, Arehally, Beluru, Biccodu, Gendehalli, Hagare, Goruru, Hassan, Kattaya, Salagame, Ballupete, Hanbalu, Shukravarsanthe, Yelsuru, Sakaleshapura, Hosuru, Belagodu, Hallibailu, Hethuru, Alduru, Chikkamagaluru, Malaluru, Malanduru, Vastare, Joldal, K.R.Pete, Gonibeedu, Kottigehara, Kalasa, Mudigere, Javali, Belluru and Hosakere.

c. The Southwest monsoon season rainfall trend thought the period of the study shows a non-significant increasing trend in Kodlipete, Alur, Channahalli, Kundur, Mallipatna, Beluru, Hagare, Gorur, Hassan, Kattaya, Salagame, Yelsuru, Sakaleshapura, Belagodu, Hallibailu, Malaluru, Malanduru, Joldal, Kottigehara, Mudigere, Javali, Hosakere and no trend is found in Gendehalli and Chikkamagaluru.

d. The Post monsoon season rainfall trend thought the study shows a non-significant increasing trend in Sanivarasanthe, Kattaya, Maranahalli, Alduru, Kottigehara and Hosakere, other stations have shown a non- significant decreasing trend.

DECLARATION STATEMENT

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