RAINFALL TREND ANALYSIS FOR THE MAHANADI MAIN CANAL COMMAND, CHHATTISGARH, INDIA

Manoj Prabhakar Kaiwart[1], P. K. Mishra[2] and Jitendra Sinha[3]
[1,3]*Soil and Water Engineering, SVCAET&RS, IGAU, Raipur (C.G), India*
[2]*Water Resources Systems Division, National Institute of Hydrology, Roorkee (Uttarakhand), India*
C*orresponding author email: kaiwart.manoj@gmail.com*

Abstract: The present study performs spatial and temporal variability of rainfall, which have been investigated in eight districts in and around the Mahanadi main canal command (MMCC). The data considered in the analysis is over the period of 102 years (1901– 2002) for rainfall. Analysis has been done on the basis of annual and seasonal time series. Homogeneity test or change point detection has been done using three methods. Those are Pettitt's test, Standard Normal Homogeneity test (SNHT), and Buishand's test. Change point analysis has been carried out to get the possible shift change point in a time series. Further, overall time series have been sub-divided into three time steps for trend analysis utilizing Mann-Kendall (MK) tests and Sen's slope estimator test viz. Entire time series, before change point and after change point for rainfall. Mann-Kendall test indicated a significant decreasing annual rainfall in the six districts viz. Dhamtari, Durg, Kanker, Mahasamund, Raigarh, Raipur and non-significant decreasing and increasing trend respectively in the Bastar (MK statistics (z) = -1.24) and Bilaspur (MK statistics (z) = +1.01) district. Spatial distribution of change percentage in annual and seasonal time sets has been analyzed for identification of variation with respect to time by spatial interpolation technique such as inverse distance weighted the spatial pattern over command area in GIS environment. The analysis divulges the significantly decreasing annual rainfall and non-significantly increasing post monsoon rainfall over canal command.

Key words: *Trend, Homogeneity test, Mann-Kendall test, MMCC region.*

1. Introduction

Food Security in the future while using water resources in a sustainable manner will be a major challenge for current and future generations. Increasing population, economic growth and rising temperature all add to increasing pressure on available water resources. Agriculture is a key water user and careful monitoring of water productivity in agriculture and exploring opportunities to increase it is required. Improving water productivity often represents the most important avenue to cope with increased water demand in agriculture. Systematic monitoring of water productivity through the use of Remote Sensing techniques can help to identify water productivity gaps and evaluate appropriate solutions to close these gaps (FAO 2018).

The climate change is the major factor in the field of agriculture, it directly affects the productivity and it's dropping year by year where the economic growth contribution for any country also affected. Food production systems are extremely sensitive to climate changes like changes in temperature and precipitation, which may lead to outbreaks of pests and diseases, thereby reducing harvest ultimately affecting the food security of the country (Mahato, 2014). Climate change is likely to directly impact food production across the globe. An increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce the yield. In areas where temperatures are already close to the physiological maxima for crops, warming will impact yields more immediately (IPCC, 2007).

Rainfall trend analyses may help predict future climate scenarios and thereby allow planning of effective and sustainable water resources management for the region (Nema *et al.*, Mahilange and Das, 2018). Investigated at four stations of Jaraikela catchment of Brahmani river basin in annual, monthly and seasonal time steps. The annual rainfall and temperature show an increasing trend at all stations (Padhiary J. *et al.*, 2018). Mann-Kendall test for the temporal trend analysis in monthly average daily ET_0 and the total annual ET_0 and the Sen's method was used to estimate the rate of change in ET_0 during the study period. (Shweta Y. *et al.*, 2016) (Koffi Djaman *et al.*, 2018). Spatial analysis using inverse distance weighted interpolation method (IDW) used for the determining the tempretuture variation. The annual mean temperature in the southern parts of the basin shows a significant positive trend (Thakur *et al.*, 2019).

2. Study Area

The study is carried out in the Mahanadi main canal command area of Chhattisgarh, which is lying approximately between 18˚00'N to 23˚20'N latitudes and between 81˚20'E and 84˚00'E longitudes. Mahanadi main canal command is a major irrigation system commissioned after the construction of the dam across the Mahanadi River. It provides irrigation facility to about 301 Km^2 (CCA) in Bastar, Bilaspur, Dhamtari, Durg, Kanker, Mahasmund, Raigarh and Raipur districts.

Location of the district headquarters and its spatial distribution of average annual rainfall have been shown in (Figure 1) In this study meteorological seasons (i.e. Pre monsoon season: March – May, monsoon season: June – September, post monsoon season: October –December and winter season: January – February) have been considered as per India Meteorology Department, Govt. of India.

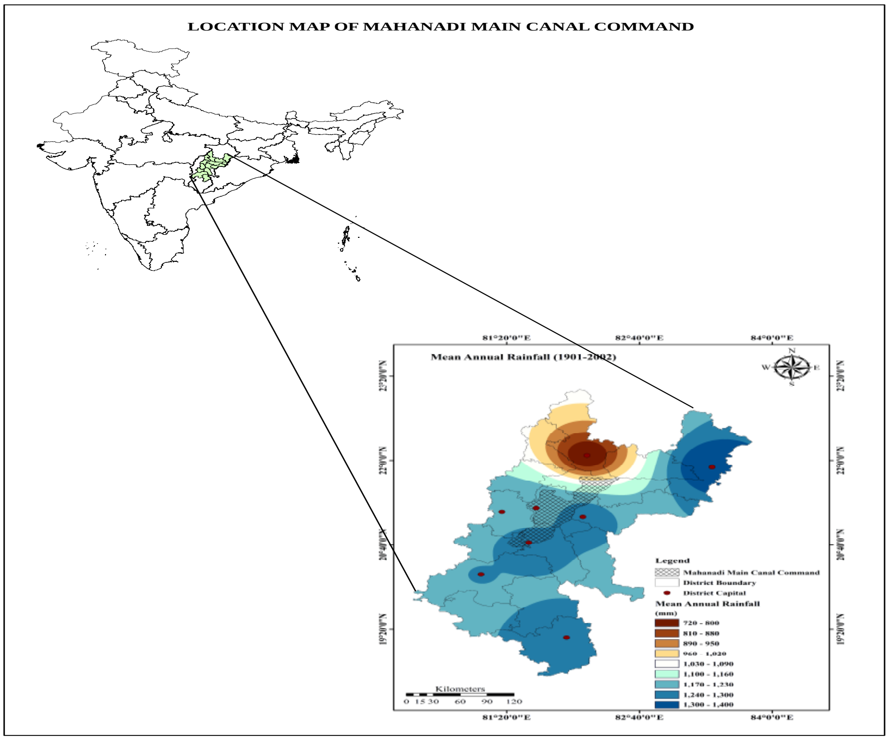


Fig 1: Location map and annual rainfall variability in and around the study area

2.1 Details of Data

Monthly rainfall of 8 districts falling in and around the Mahanadi Main Canal Command (MMCC) have been acquired from India Water Portal site (http://indiawaterportal.org/met_data/) for a period of 102 years (1901-2002).

3. Methodology

The following method used for the spatial and temporal analysis of the long term monthly data of the Mahanadi main canal command area.

Mann- Kendall test were applied for the data analysis of annual and seasonal Rainfall trend (Mann, H. B. 1945) and (Kendall, M. G. 1975).

The magnitude is estimated by the theil and sen's slop estimator (Sen, P.K. 1968).

Homogeneity test was applied for the change point detection in the command area which is tested by the Pettitt's test (Pettitt, A.N. 1979), SNHT test (Alexandersson, H.1986) and Buishand's test (Buishand, T.A. 1982) .

Spatial anysis of of the Rainfall over the Mahanadi main canal command inverse distance, the weighted interpolation technique was used in-built in the Arc GIS environment (Pai, D.S. *et al.*, 2014).

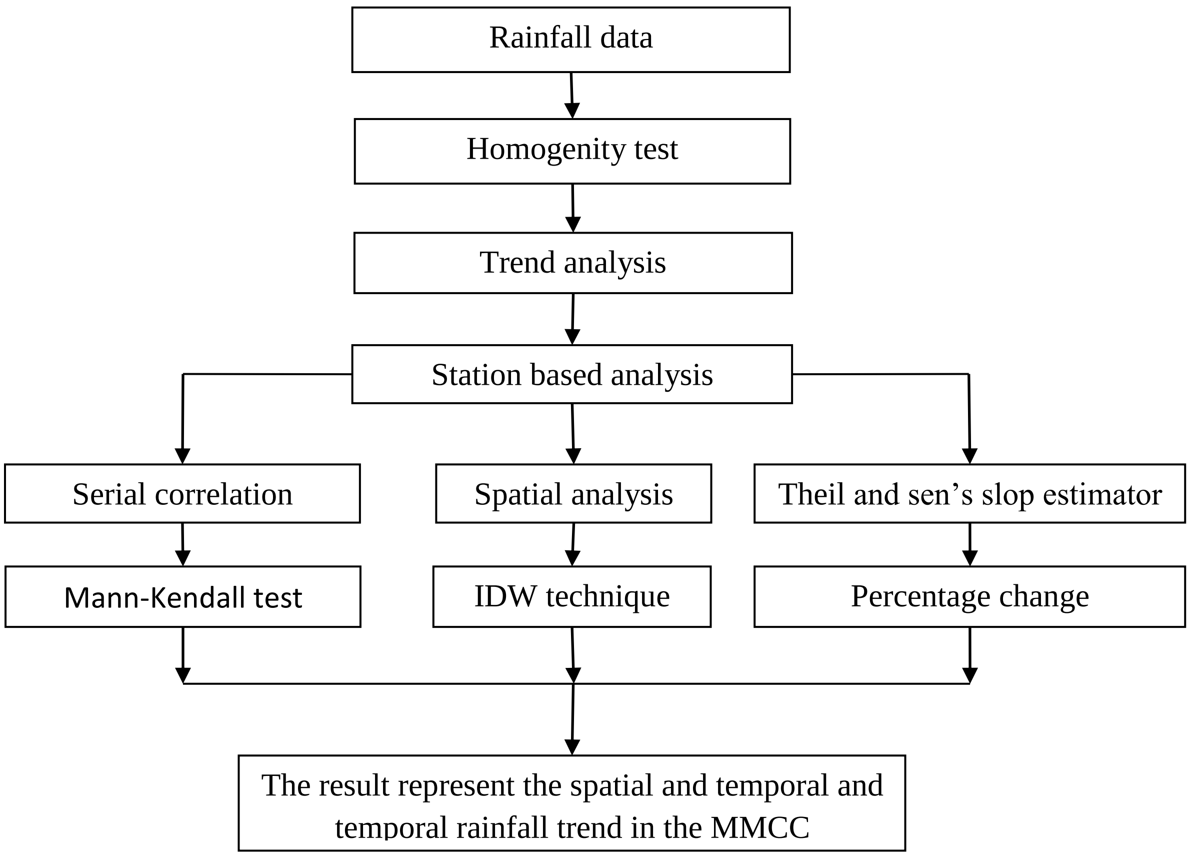


Fig No. 2: Procedures of analysis methodology used in MMCC area

4. RESULTS AND DISCUSSION

The detailed trend analysis of rainfall during the period 1901-2002 on seasonal and annual basis was carried out in the current study by using the Mann-Kendall test and Sen's slope estimator for 8 districts of Mahanadi main canal command. Percentage change in annual and seasonal rainfall was also determined to show the change in trend.

Inverse Distance Weighted (IDW) interpolation technique has been used for detecting the spatial distribution of rainfall over Mahanadi main canal command. The increasing, decreasing trend with the significance level and no trend in rainfall are represented in figures (4 –a,b,c,d,e) with different symbols.

4.1 Primiraly data analysis

The study commenced with finding the general statistics of annual average rainfall time series for 102 years (1901-2002) for different districts in and around Mahanadi main canal command (Table No. 1). The general statistics on annual and seasonal rainfall series for the Mahanadi main canal command are given in (Table No. 2). The analysis revealed that the annual rainfall varies between 737 mm (Bilaspur) to 1379 mm (Raigarh) over Mahanadi main canal command. The annual average rainfall of the entire canal command is calculated as 1197 mm. The seasonal analysis revealed that the maximum rainfall is received during four monsoon months viz. June to September. The region also witnessed non significant post-monsoon and winter rainfall. The box plots of these statistics and relative frequency of occurrence of rainfall are shown in (Figure No. 2). From the analysis, it has been observed that the standard deviation varies from178 mm (Raipur) to 211 mm (Bilaspur, Durg and Raipur). Coefficient of variance varies between 15% (Durg, Raigarh and Raipur) and 24% (Bilaspur). The skewness is measure of asymmetry of frequency distribution from the mean, varied between 0.15 (Raigarh) and 0.49 (Bilaspur). All the districts have shown positive skewness in annual rainfall series. Kurtosis is a statistical measure used to describe the distribution of observed data around the mean, and varies from -0.10 (Raigarh) to 0.33 (Dhamtari). It can be seen from Table 4.1 that the tail-end of the Mahanadi main canal command (Bilaspur) is receiving less rainfall in comparison to the head-end (Dhamtari, Kanker). It can be further concluded from the results that the zone of usually heavy rainfall shows least variability and zone of low rainfall indicates the highest variability.

Table 1: General statistics of annual rainfall (mm) for different districts in and around Mahanadi main canal command

Statistics	Bastar	Bilaspur	Dhamtari	Durg	Kanker	Mahasamund	Raigarh	Raipur	Mahnadi Region
Mean	1251	737	1259	1219	1237	1279	1379	1219	1197
Standard Deviation	201	178	198	178	199	188	211	178	161
CV	16	24	16	15	16	15	15	15	13
Kurtosis	0.08	-0.31	0.33	-0.21	-0.48	0.23	-0.10	-0.21	-0.11
Skewness	0.29	0.49	0.41	0.31	0.16	0.40	0.15	0.31	0.31
Maximum	1821	1176	1865	1699	1753	1796	1931	1699	1640
Minimum	760	397	873	857	788	899	911	857	874
Median	1228	705	1239	1201	1221	1261	1370	1201	1183

Table 2: General statistics of annual and seasonal rainfall (mm) in and around Mahanadi main canal command

Statistics	*Rainfall (mm)*				
	Annual (Jan-Dec)	*Pre Monsoon (Mar-May)*	*Monsoon (Jun-Sep)*	*Post Monsoon (Oct-Nov)*	*Winter (Dec-Feb)*
Mean	1195	59	1046	63	27
Standard Deviation	163	26	148	40	15
CV	14	43	14	63	56
Kurtosis	-0.14	-0.13	-0.04	-0.02	0.93
Skewness	0.31	0.53	0.24	0.70	0.97
Maximum	1640	127	1457	173	84
Minimum	874	11	732	4	4
Median	1182	57	1024	60	23

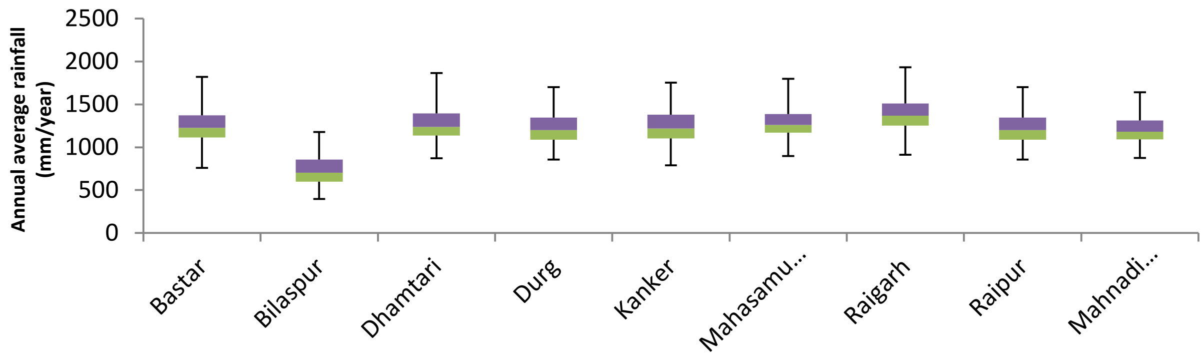


Fig 2: Box plots showing annual average rainfall of different districts in and around Mahanadi main canal command

4.2 Change Point Detection in Mahanadi main canal command

Table 3 and graph below shows break point in rainfall trend during 1901-2002 (102 years) over eight districts of the Maahanadi Canal Command. Change points obtained for rainfall varies for different districts, but most of the districts have shown 1961 as a change point. Few districts indicate the later part of seventies (1974) and early part of ninties (1995) when a significant variation seen in the rainfall series. Before the application of MK test to detect trends, serial correlation of these series were tested to detect randomness.

Table 3: Results of Homogeneity test on rainfall series on different districts

Districts	Rainfall (mm)								
	Pettitt's test			SNHT test			Buishand's test		
	K	t	P	$T_0^{\#}$	t	P	Q	t	P
Bastar	643	1963	0.295	3.184	1961	0.575	9.718	1961	0.255
Bilaspur	516	1974	0.726	5.659	1974	0.280	10.77	1974	0.158
Dhamtari	829	1961	0.062	7.829	1961	0.114	13.92	1961	0.032
Durg	909	1961	0.025	8.476	1961	0.061	14.49	1961	0.019
Kanker	857	1961	0.047	7.765	1961	0.091	13.87	1961	0.031
Mahasamund	923	1961	0.023	10.93	1995	0.023	15.83	1961	0.009
Raigarh	925	1949	0.019	17.35	1991	0.001	16.17	1961	0.008
Raipur	909	1961	0.023	8.476	1961	0.067	14.49	1961	0.021
Mahanadi region	867	1961	0.042	8.597	1995	0.060	13.94	1961	0.029

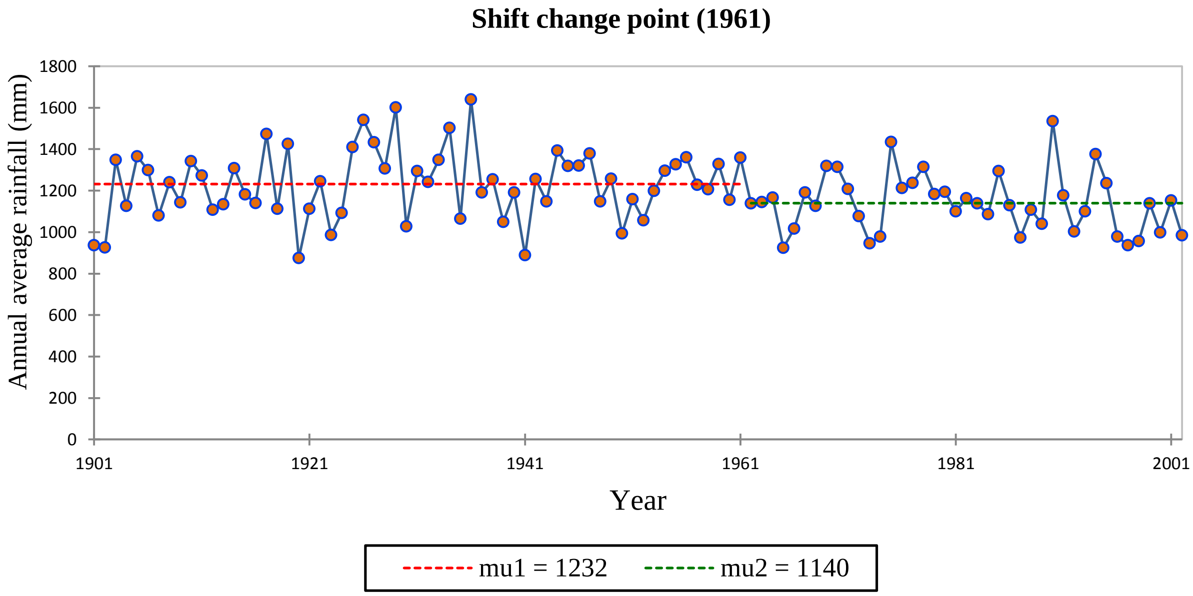


Fig 3: Chang point detection Average aanual rainfall over MMCC

4.3 Rainfall Trend Analysis (Annual and Seasonal)

4.3.1 Entire time series of the MMCC (1901-2002)

The spatial distribution of rainfall trend on seasonal (pre-monsoon, monsoon, post-monsoon & winter) and annual basis with symbolic representation of positive significant, positive non-significant, negative significant, negative non-significant and no trend over 8 districts of Mahanadi main canal command are shown in (Figure No 4). (Table No. 4) shows the value of Mann-Kendall test statistic (Z), Magnitude of Sen's slope (β) and percentage change of rainfall at seasonal and annual temporal scales for all the districts of Mahanadi main canal command. On a temporal scale insignificant decline trend in annual and winter rainfall was observed. While the Pre and post monsoon rainfall trend was increasing over the period 1901-2002 over Mahanadi main canal command. Many significant variations in rainfall trend were observed in the study area. A wide variation of change rate was also found at different districts. Mann-Kendall test indicated a significant decreasing annual rainfall in the six districts viz. Dhamtari (-2.30), Durg (-5.27), Kanker(-2.13), Mahasamund (-2.78), Raigarh (-2.81), Raipur (-2.57) and non-significant decreasing and increasing trend respectively in the Bastar (-1.24) and Bilaspur (+1.01) district at the 1%, 5% and 10% level of significance respectively.

Mann-Kendall test indicated non significant decrease in rainfall during winter season in most of the districts over the MMC. The decrease in rainfall and change percentage are: Bastar (-1.01 mm/year and -24.84%), Bilaspur (-0.04mm/year and -5.44%), Dhamtari (-0.01 mm/year and -5/16%), Kanker (-0.36 mm/year and -7.89%), Mahasamund (-0.55 mm/year and -12.92%), Raigarh (-0.71mm/year and -16.08%).

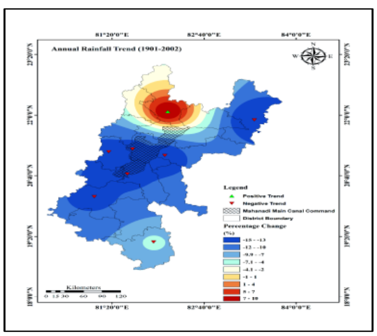
4.3.2 Before Break Point of the MMCC (1901-1961)

The annual rainfall series before the break point i.e. during 1901 to 1961, all the districts showed non significant positive trend. Unlike a singnificant positive trend in the whole series (1901-2011) in most of the districts. Where the post monsoon trends also showed a significant increasing trend in most of the districts, unlike during 1901-2002 in all the districts during the period. Similar to the trends when the whole series is considered, the trends during pre-monsoon, monsoon and winters were non-significant.

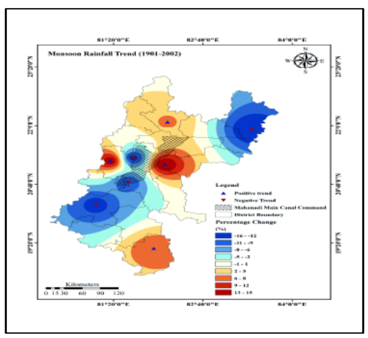
4.3.3 After Break Point of the MMCC (1963-2002)

After the break point, the annual and monsoon series showed non-significant negative (Bastar, Dhamtari, Durg, Kanker, raigarh) as well as Positive (Bilaspur) trends. The points which was to be noticed that Bastar, Dhamtari, Durg, Kanker, Raigarh districts though preserve the increasing rainfall trend as it was during 1901-1961, but with a nonsignificant level. However, in case of districts namely Mahasmund and Raigarh the trends reversed from non significant positive to significantant negative trends in annual and monsoon series.

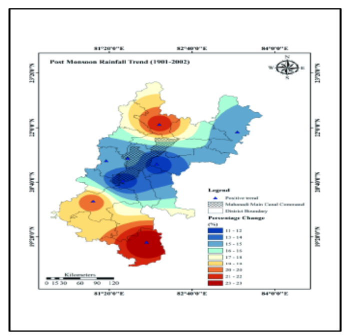
Pre-monsoon data sets of all districts showed non-significant negative trends, except three districts indicated non-significant positive trend namelyBilaspur (+0.55 mm/ year), Durg (+0.24 mm/ year) and Raipur(+0.24). During post-monsoon, excepting the districts of Raipur (+1.85 mm/ year) and Dorg (+1.85 mm/year), rest of the districts showed non-significant positive except Bilaspur (-0.37 mm/year). Entire winter showed a negative trends in most of the districts except Bilaspur (+0.44 mm/year).



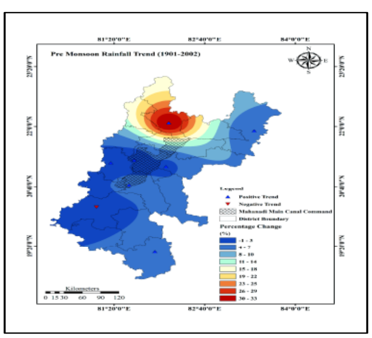
(A)



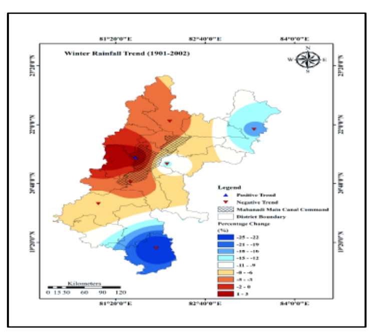
(B)



(C)



(D)



(E)

Figure 4: Annual (A) and Seasonal (B: Pre-monsoon; C: Monsoon; D: Post-monsoon; E: Winter) rainfall trends and percentage of change during 1901-2002 over eight districts in and around Mahanadi main canal command

Table No 4: Average annual and seasonal rainfall time series

1901-2002	Annual				Pre-Monsoon				monsoon				Post-Monsson				Winter			
Districts /State	Test Z	Significance	β	% Change	Test Z	Significance	β	% Change	Test Z	Significance	β	% Change	Test Z	Significance	β	% Change	Test Z	Significance	β	% Change
Bastar	-1.24	#	-0.84	-6.85	0.33	#	0.05	5.68	-1.27	#	0.74	7.28	1.12	#	0.24	22.84	-1.01	#	-0.04	-24.84
Bilaspur	1.01	#	0.69	9.50	2.10	$$	0.17	32.96	0.31	#	0.31	5.20	0.84	#	0.03	21.17	-0.04	#	-0.04	-5.44
Dhamtari	-2.30	$$	-1.64	-13.28	0.29	#	0.03	4.25	-2.15	$$	-1.31	-12.05	0.47	#	0.07	10.90	-0.22	#	-0.01	-5.16
Durg	-2.57	$$$	-1.62	-13.54	0.02	#	0.00	0.43	-2.65	$$$	1.44	13.59	0.72	#	0.09	14.20	0.13	#	0.01	3.07
Kanker	-2.13	$$	-1.60	-13.22	-0.04	#	-0.01	-0.81	-2.16	$$	-1.48	-14.03	0.95	#	0.15	19.82	-0.36	#	-0.01	-7.89
Mahasamund	-2.78	$$$	-1.80	-14.43	0.11	#	0.01	2.27	-2.79	$$$	1.67	15.07	0.49	#	0.06	11.11	-0.55	#	-0.03	-12.92
Raigarh	-2.81	$$$	-2.08	-15.42	0.21	#	0.02	3.71	-2.61	$$$	-1.92	-15.82	0.63	#	0.07	13.69	-0.71	#	-0.05	-16.08
Raipur	-2.57	$$$	-1.62	-13.54	0.02	#	0.00	0.43	-2.65	$$$	-1.44	-13.59	0.72	#	0.09	14.20	0.13	#	0.01	3.07
1901-1961																				
Bastar	1.24	#	2.07	9.87	0.60	#	0.24	16.98	0.65	#	1.03	5.84	2.51	$$	1.26	70.70	-1.84	$	-0.15	-54.97
Bilaspur	0.60	#	0.74	6.30	-0.14	#	-0.02	-2.24	0.36	#	0.28	2.91	1.57	#	0.13	55.18	0.36	#	0.10	8.94
Dhamtari	0.75	#	1.09	5.12	1.09	#	0.29	27.11	0.33	#	0.55	2.91	2.38	$$	0.80	66.57	-1.39	#	-0.12	-41.94
Durg	0.75	#	1.13	5.48	0.85	#	0.12	15.47	0.36	#	0.38	2.06	2.27	$$	0.68	62.36	-0.90	#	-0.09	-24.08
Kanker	0.75	#	1.23	5.86	0.55	#	0.17	16.06	0.44	#	0.78	4.26	2.25	$$	0.86	66.62	-1.40	#	-0.12	-43.06
Mahasamund	0.69	#	0.89	2.76	0.48	#	0.11	7.37	0.43	#	0.55	1.91	2.18	$$	0.67	44.61	-1.30	#	-0.14	-24.88
Raigarh	0.80	#	1.26	5.35	0.32	#	0.06	7.06	0.80	#	1.05	4.95	2.06	$$	0.55	59.74	-1.28	#	-0.18	-37.51
Raipur	0.75	#	1.13	5.48	0.85	#	0.12	15.47	0.36	#	0.38	2.06	2.27	$$	0.68	62.36	-0.90	#	-0.09	-24.08
1962-2002																				
Bastar	-0.03	#	-0.07	-0.24	-0.06	#	-0.04	-1.78	0.15	#	0.42	1.71	1.05	#	0.84	33.45	-1.09	#	-0.18	-41.98
Bilaspur	0.30	#	0.74	4.00	0.55	#	0.16	11.01	-0.06	#	-0.22	-1.44	-0.37	#	-0.04	-9.80	0.44	#	0.14	9.41
Dhamtari	-1.00	#	-2.25	-7.76	-0.12	#	-0.06	-4.38	-0.64	#	-1.45	-5.66	1.27	#	0.71	47.94	-0.73	#	-0.12	-26.42
Durg	-1.13	#	-2.60	-9.24	0.24	#	0.08	7.07	-1.11	#	-2.11	-8.42	1.85	$	0.71	51.96	-0.48	#	-0.10	-17.22
Kanker	-0.03	#	-0.19	-0.68	-0.24	#	-0.11	-7.64	-0.06	#	-0.22	-0.87	1.52	#	0.92	52.16	-0.71	#	-0.13	-26.86
Mahasamund	-1.67	$	-4.78	-16.28	-0.39	#	-0.19	-12.23	-1.74	$	-3.96	-15.24	1.31	#	0.62	48.08	-0.48	#	-0.13	-22.21
Raigarh	-2.01	$$	-6.23	-19.76	-0.17	#	-0.09	-6.53	-1.97	$$	-6.14	-21.71	1.20	#	0.46	37.95	-0.35	#	-0.10	-15.06
Raipur	-1.13	#	-2.60	-9.24	0.24	#	0.08	7.07	-1.11	#	-2.11	-8.42	1.85	$	0.71	51.96	-0.48	#	-0.10	-17.22

Where $$$, $$, and $ values shows significance level at 1% (2.577), 5% (1.96), and 10% (1.645) respectively; # indicates non-significant trend; Negative (-) and positive (+) values indicate the decreasing and increasing trends respectively.

5. CONCLUSIONS

In the present study, the spatial and temporal variability of rainfall, have been investigated in eight districts in and around the Mahanadi main canal command. The data considered in the analysis is over the period of 102 years (1901– 2002) for rainfall. Homogeneity tests using three methods Pettitt's test, Standard Normal Homogeneity test (SNHT), and Buishand's test were carried out to get the possible shift change point in a time series. Further, overall time series has been sub-divided into three time steps for trend analysis utilizing Mann-Kendall (MK) tests and Sen's slope estimator test viz. entire time series, before change point and after change. The average annual rainfall in the command is significant in the Mahanadi main canal command (1046 mm), received mainly during 'monsoon' followed by 'postmonsoon' and 'pre-monsoon'; Least in 'winter'. The annual maximum rainfall is witnessed in the districts of Raigarh (1379 mm) followed by Dhamtari (1259 mm). Mann-Kendall test indicated a significant (5% significance level) decreasing annual rainfall in the six districts viz. Dhamtari, Durg, Kanker Mahasamund, Raigarh and Raipur and non-significant decreasing and increasing trend respectively in the Bastar (MK statistics (z) = -1.24) and Bilaspur (MK statistics (z) = +1.01) district. Sen's slope estimate suggested a percentage decrease in the range of 9.50% (Bilaspur) to 13.54% (Raipurnad durg) rainfall over the last 102 years in the annual rainfall in the Mahanadi region. Overall, the Mahanadi region showed decreasing rainfall trend in the annual rainfall series.

REFERENCES

1. Alexandersson, H., (1986), A homogeneity test applied to precipitation data. Journal of Climatology 6(6), 661–675. doi: 10.1002/joc.v6:6
2. Buishand, T.A., (1982), Some methods for testing the homogeneity of rainfall records. Journal of Hydrology 58(1–2), 11–27. doi: 10.1016/0022-1694(82)90066-X
3. FAO (2018), WaPOR Database Methodology: Level 1. Remote Sensing for Water Productivity Technical Report: Methodology Series. Rome, FAO. 72 pages. License: CC BY-NC-SA 3.0 IGO.
4. Kendall, M. G. (1975), Rank Correlation Methods. Griffin, London.
5. Koffi Djaman, Papa Malick Ndiaye, Komlan Koudahe, Ansoumana Bodian, Lamine Diop, Michael O'Neill and Suat Irmak (2018), Spatial and temporal trend in monthly and annual reference evapotranspiration in Madagascar for the 1980-2010 period, International Journal of Hydrology, Vol. 2, Issue 2.
6. Mahato A. (2014), Climate Change and its Impact on Agriculture, International Journal of Scientific and Research Publications, Volume 4, Issue 4, April 2014, ISSN 2250-3153.
7. Mahilange M. and Das G.K. (2018), Analysis of rainfall trend in five districts of northern hill zone of Chhattisgarh state, Journal of Pharmacognosy and Phytochemistry; 7(5): 3283-3286
8. Mann, H. B. (1945), Nonparametric tests against trend. Econometrica 13, 245–259.
9. Nema M.K., Khare D., Adamowski J. and Chandniha S.K. (2018), Spatio-temporal analysis of rainfall trends in Chhattisgarh State, Central India over the last 115 years, Journal Of Water And Land Development, No. 36 (I–Iii): 117–128, Pl Issn 1429–7426.
10. Pai, D.S., Sridhar, L., Rajeevan, M., Sreejith, O.P., Satbhai, N.S. and Mukhopadhyay, B., (2014), Development of a new high spatial resolution (0.25× 0.25) long period (1901–

2010) daily gridded rainfall data set over India and its comparison with existing data sets over the region. Mausam 65(1), 1–18.

11. Padhiary J., Das D.M., Patra K.C. And Sahoo B.C. (2018), Trend Analysis Of Rainfall And Temperature Using The Mann Kendall Test In Jaraikela Catchment Of Brahmani River Basin, International Journal Of Agriculture Sciences, Issn: 0975-3710 & E-Issn: 0975-9107, Volume 10, Issue 19, 2018, Pp.-7309-7313
12. Pettitt, A.N., 1979, A non-parametric approach to the change-point problem. Journal of the Royal Statistical Society: Series C (Applied statistics) 28(2), 126–135.
13. Sen, P.K., (1968), Estimates of the regression coefficient based on Kendall's tau. Journalm of the American Statistical Association 63(324), 1379–1389. doi: 10.1080/01621459.1968.10480934
14. Shweta Y., Proloy D., Sonn K.,Vanita P. and Pankaj Kumar p. (2016)., Trends in major and minor meteorological variables and their influence on reference evapotranspiration for mid Himalayan region at east Sikkim, India, Journal of Mountain Science 13(2):302-315.
15. Thakur A, Mishra P.K., Nema A. K. and Sahoo S.P. (2019), Spatio-temporal trends and shift analysis of temperature for Wainganga sub-basin, India, International Journal of Environmental Studies, DOI: 10.1080/00207233.2019.1686884