ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 10| Issue: 3| March 2024|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2024: 8.402 || ISI Value: 1.188

ANALYSIS OF RAINFALL TREND USING NON- PARAMETRIC METHODS AND INNOVATIVE TREND ANALYSIS TECHNIQUE DURING 1901-2019 IN ODISHA

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ABSTRACT

Annual Rainfall, has received a great deal of attention worldwide by researchers. The degree of variability or fluctuations in the factor varies according to locations. Hence, examining the trend of rainfall in Odisha state where agriculture plays a vital role in the state's economy, which depends on monsoonal rainfall. Any change in rainfall pattern can adversely affect the agricultural production and economy of Odisha. This study examines the long-term changes and short-term fluctuations in annual and seasonal rainfall in the state of Odisha. The study analyzed the rainfall data for a period of 119 years (i.e. 1901–2019) as a whole and also at the micro scale for the state of Odisha. It used the statistical trend analysis techniques, namely Mann-Kendall (MK) test, and Sen's slope estimator and Regression line for examining the trend direction and magnitude of the change over the study period. The observed variation in rainfall at different scales revealed that, the monsoon season has maximum contribution to annual rainfall and it does not have any strong trend over the study period. The outcomes of the study gives district-wise information on rainfall trends on a long-term basis , which will be helpful for the Hydrological resources department for planning and management of hydrological resources for its sustainable use and particularly for the benefits of agricultural sectors.

KEYWORDS: *Rainfall Trend Analysis, Mann-Kendall (MK) test, Sen's Slope Estimator Test, Regression Technique.*

INTRODUCTION

The changes in rainfall have caused changes in intensity and frequency of climate events such as droughts and floods, which have a great impact on human life and socio-economic features of India (Janadas and Ambuja, 2019).According to the report of the Intergovernmental Panel on Climate Change (IPCC), Precipitation is the most significant factors in the list of climatic variables, commonly used to trace the level and magnitude of climate change and variability (IPCC, 2007). According to other Researchers, rainfall (Singh et al., 2013) is the most essential physical parameters among the climatic variables. These variable regulate the environmental condition of a particular area which affects the agricultural production of that region (Modarres and da Silva, 2007; Kumar and Gautam, 2014). On the other hand the increasing demographic pressure and variation in climate exaggerated the concern for the availability of usable and drinkable freshwater resources (Vorosmarty et al., 2000; Gleick, 1993, 2000; Shiklomanov et al. 2003; Milliman et al., 2008).According to the study of Chaouche et al. (2010), some region is very much sensitive to the results of climate change. According to some researchers, the rising pressure of humans on the land-use pattern is the major cause of extreme weather and change in climatic parameters like rainfall (Alcamo et al. 2003; Arnell et al., 2004).

Odisha has primarily an agriculture-based economy. It contributes nearly 30% to the Net State Domestic Product (NSDP) and about 73% of people engaged in this sector (Planning commission 2001). The agricultural area of Odisha is about 61.80 lakh hecteres, about 54% of cultivable land has an irrigation facility (Odisha agriculture statistic report, 2014). Therefore, natural rainfall plays a most significant role in Odisha's economy in agriculture.

According to the Odisha state disaster management authority, Droughts are also being experienced by Odisha each year in some regions or the other. During the last 50 years, natural events have affected the state for 41 years out of which drought had hit 19 years. Abnormal rainfall is the most significant factor for severe drought condition in Odisha. The monsoon rain that comes at the end of the October and its pattern does not benefit the state's agriculture activity. Thus, there is an urgent need to pay proper attention to the variation of rainfall as it affect the availability of fresh water and agricultural production (Dore, 2005).

Therefore, the major aim of this study or research is to analyze the Trend of the Rainfall of Odisha. Annual and seasonal trends of rainfall have been studied in this research. The prime objective is to explore the trend in rainfall of Odisha during 1901-2019 at district level. The specific objectives are to analyze the trends of rainfall on an annual and seasonal by using non-parametric test and trend of rainfall by Regression line. Here, we compare the two technique data of trend analysis .In this study, we can get knowledge about the rainfall trend.

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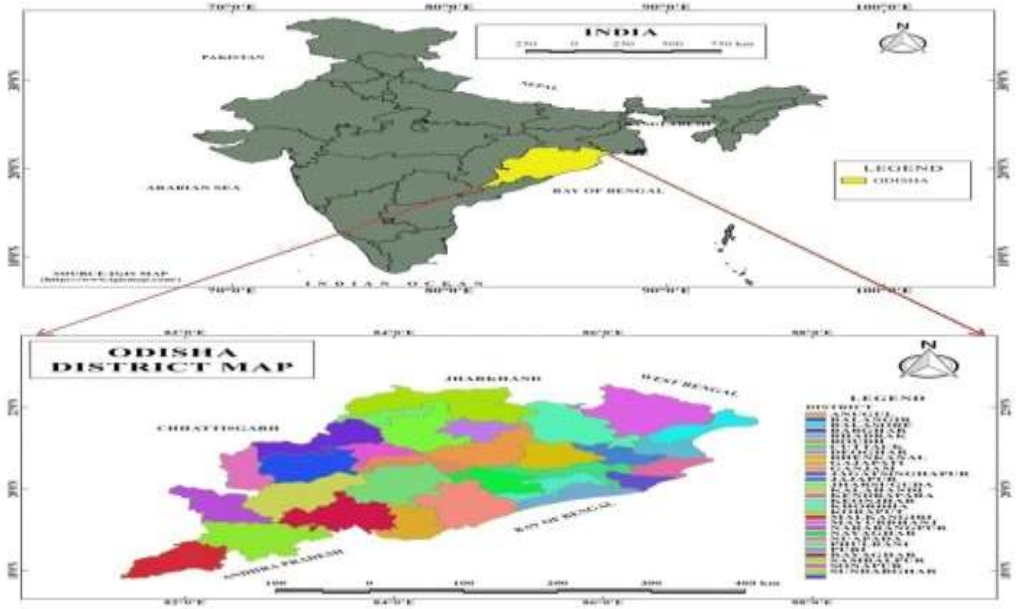
STUDY AREA

Odisha coastal state lies in the north-eastern part of the Indian Peninsula with 450 km long coastline. The Odisha state comprises 30 districts and covers an area of 1,55,707 sq. km, making it the 9th largest state in the country in terms of area and it is 4.87% of India's whole geographical area.

The Odisha state is coming from a tropical climate. Odisha states observed high temperature, high humidity, about 200cm rainfall varies from medium to high, and short, minor winters. The south-west monsoon comes in between 5th June and 10th June in the coastal area of Odisha. Odisha receive 1451.2 mm of normal rainfall. About 75% to 80% of rainfall is received during the Monsoon season from June to September. The part of the cropped area of Odisha under different crops has increased from 42.37% to 43.79% in 2014-15 to 2018-19, respectively. About 61 lakh hectors of irrigation potential were created in 2018-19 compared to 51.8 lakh hectors in 2014-15. In Odisha, more than 83% of the total population lives in rural areas and depends on the primary activity, i.e. agriculture. Water-consuming rice is its main crop, which needed 200cm of rainfall for cultivation.



DATA AND METHODOLOGY

Rainfall data of Odisha from 1901 to 2019 for 119 years is considered for analysis of trend of rainfall . These data have been obtained from the India Water Portal and State Relief Commission of Odisha. The study is based upon secondary data sources which are freely available by these organizations. The monthly rainfall data were collected district-wise and categorized into four seasons such as: Winter Season (Jan-Feb), Pre-Monsoon Season (March-May), Monsoon Season (June-Sept), Post-Monsoon Season (Oct-Dec). Statistical methods, such as regression analysis (Deshmukh,2013) is used. The non-parametric tests such as the MK test and Sen's Slope estimator test (is done by using XLSTAT 2014 software) have been used in this study for trend analysis. In this study, we can show the trends of rainfall by using two techniques.

DATA ANALYSIS TECHNIQUE

The MK test is a statistical non-parametric test widely used for trend analysis in climatological and hydrological time series data. This non-parametric test was suggested by Mann (1945) and has been widely used in climatological and environmental time series analysis. The two main advantages of using this non-parametric statistical test is:-the first are It is a nonparametric test, so it does not require whether the data is normally distributed or not and the second is due to inhomogeneous time series, the test has low sensitivity to abrupt breaks. The MK test is also more suitable for the outlier, censored, and missing data of the series.

The magnitude of a trend in a time series can be determined using a non-parametric method known as sen's slope estimator (sen,1968). To estimate the true slope of an existing trend, such as the amount of change per year,we use this statistical test.

The trends of Seasonal and Annual Rainfall of Odisha over different years were obtained using Linear Regression best fit lines. In the Regression equation positive "Y" values show an increase in rainfall and negative "Y" values indicate a decrease in rainfall.

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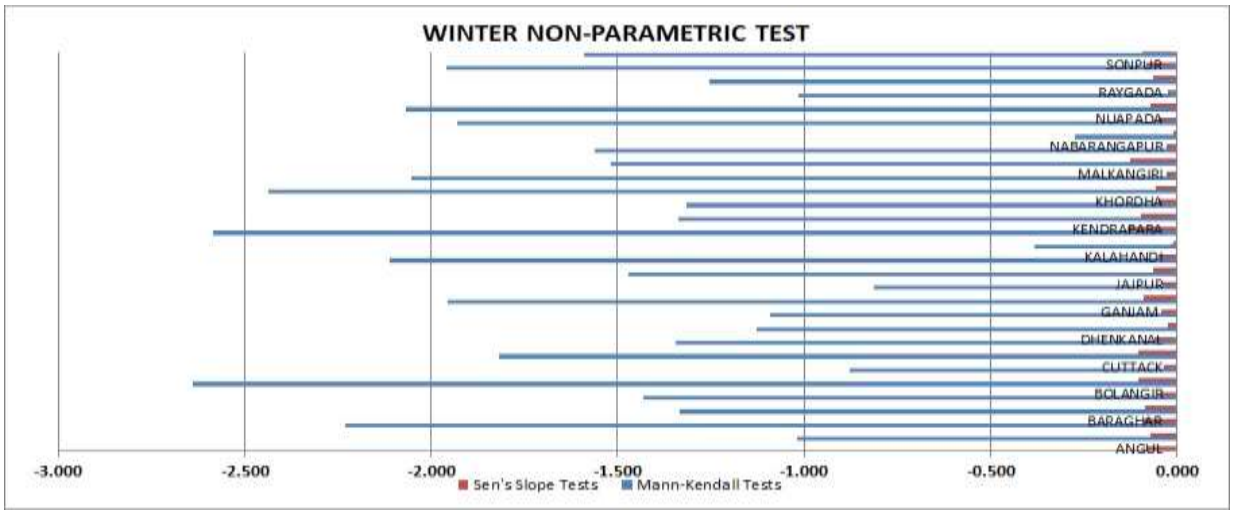
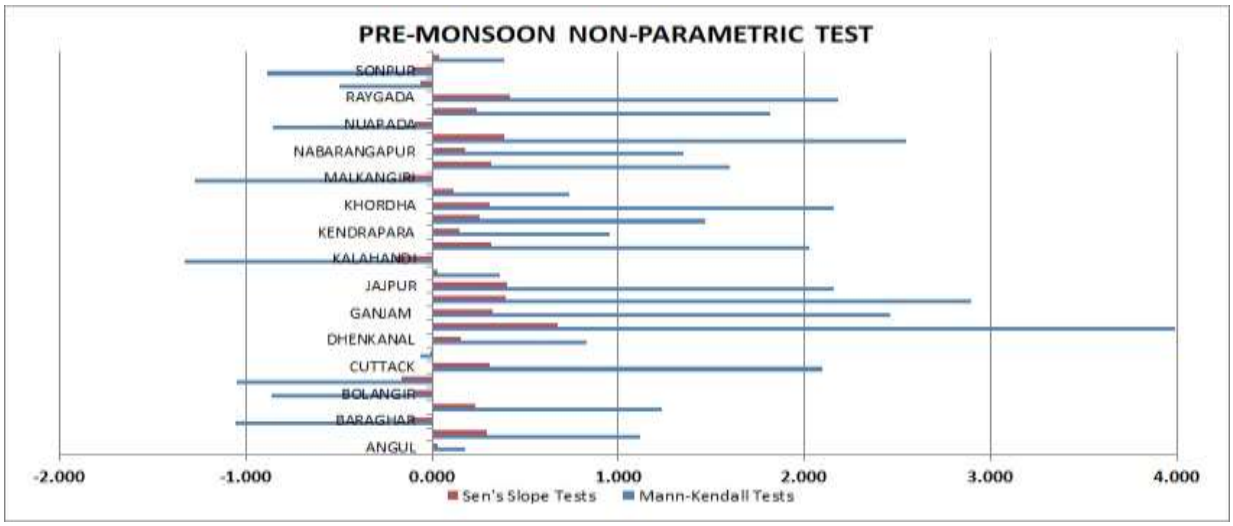
RESULTS AND DISCUSSION

a. Trend Analysis using Non–Parametric tests

DISTRICT	ANNUAL			WINTER			PREMONSOON			MONSOON			POSTMONSOON		
	P value	MK test	Sen's slope	P value	MK test	Sen's slope	P value	MK test	Sen's slope	P value	MK test	Sen's slope	P value	MK test	Sen's slope
ANGUL	0.4103	0.823	0.3544	0.1580	-1.412	-0.0771	0.8597	0.177	0.0307	0.7342	0.340	0.1418	0.4652	0.730	0.1323
BALASORE	0.0082	2.642	1.7504	0.3083	-1.019	-0.0697	0.2642	1.116	0.2924	0.1203	1.554	0.7523	0.0682	1.824	0.513
BARAGHAR	0.0048	-2.819	-1.3934	0.0257	-2.231	-0.0882	0.2910	-1.056	-0.1171	0.0156	-2.419	-1.1388	0.7115	0.370	0.034
BHADRAK	0.1519	1.433	0.8475	0.1826	-1.333	-0.0848	0.2177	1.233	0.2319	0.4912	0.688	0.311	0.1428	1.465	0.4036
BOLANGIR	0.0249	-2.242	-1.2107	0.1526	-1.430	-0.0453	0.3895	-0.861	-0.0913	0.0389	-2.065	-1.0065	0.8161	-0.233	-0.0237
BOUDH	0.4623	0.735	0.3484	0.0083	-2.638	-0.1035	0.2963	-1.044	-0.1603	0.2506	1.149	0.549	0.7873	0.270	0.034
CUTTACK	0.0001	3.791	2.433	0.3806	-0.877	-0.036	0.0363	2.093	0.3085	0.0018	3.117	1.6815	0.1959	1.293	0.419
DEOGARH	0.2703	-1.102	-0.4974	0.0693	-1.817	-0.1054	0.9518	-0.060	-0.012	0.1671	-1.382	-0.5838	0.5672	0.572	0.0744
DHENKANAL	0.0940	1.675	0.9631	0.1788	-1.344	-0.061	0.4077	0.828	0.1571	0.2212	1.223	0.5802	0.5392	0.614	0.1605
GAJAPATI	0.0001	3.884	2.4006	0.2592	-1.128	-0.0254	< 0.0001	3.991	0.677	0.0014	3.187	1.3311	0.1729	1.363	0.4965
GANJAM	0.0047	2.828	1.4963	0.2753	-1.091	-0.0421	0.0140	2.456	0.3254	0.0384	2.070	0.75	0.2041	1.270	0.431
JAGATSINGHAPUR	0.0001	3.819	2.3462	0.0505	-1.956	-0.09	0.0038	2.893	0.3918	0.0036	2.912	1.4577	0.2583	1.130	0.3817
JAJPUR	0.0062	2.735	1.6786	0.4169	-0.812	-0.0377	0.0313	2.154	0.4066	0.1035	1.628	0.906	0.1729	1.363	0.3711
JHARSUGUDA	0.0878	-1.707	-0.9274	0.1416	-1.470	-0.0628	0.7167	0.363	0.0341	0.0502	-1.958	-1.0569	0.0271	2.210	0.1997
KALAHANDI	0.6789	0.414	0.2602	0.0347	-2.112	-0.0489	0.1849	-1.326	-0.2014	0.3972	0.847	0.5335	0.7837	-0.274	-0.0393
KANDHAMAL	0.0065	2.721	1.679	0.7029	-0.381	-0.0112	0.0430	2.024	0.3207	0.0324	2.140	1.0734	0.1288	1.519	0.318
KENDRAPARA	0.0108	2.549	1.5647	0.0098	-2.584	-0.1323	0.3403	0.954	0.1501	0.0904	1.693	0.9089	0.0675	1.828	0.5428
KEONJHAR	0.3668	0.902	0.4676	0.1811	-1.337	-0.0958	0.1428	1.465	0.2558	0.9407	-0.074	-0.0285	0.1441	1.461	0.2537
KHORDHA	0.0030	2.973	1.7565	0.1880	-1.316	-0.0498	0.0309	2.158	0.312	0.0043	2.856	1.2657	0.7518	0.316	0.1249
KORAPUT	0.0083	2.638	2.0046	0.0148	-2.437	-0.0579	0.4623	0.735	0.1139	0.0031	2.954	1.8272	0.3083	1.019	0.2534
MALKANGIRI	< 0.0001	4.298	2.8572	0.0401	-2.053	-0.0276	0.2041	-1.270	-0.1534	< 0.0001	4.275	2.4045	0.2486	1.154	0.3007
MAYURBHANJ	0.0416	2.038	1.1822	0.1288	-1.519	-0.1251	0.1106	1.596	0.3147	0.2355	1.186	0.551	0.1127	1.586	0.2933
NABARANGAPUR	0.2642	1.116	0.8463	0.1186	-1.561	-0.0262	0.1758	1.354	0.1789	0.0968	1.661	1.0069	0.9592	0.051	0.0101
NAYAGARH	0.0012	3.242	1.955	0.7837	-0.274	-0.0084	0.0109	2.545	0.3873	0.0115	2.526	1.1698	0.4882	0.693	0.2188
NUAPADA	0.0003	-3.605	-2.0752	0.0535	-1.931	-0.0502	0.3946	-0.851	-0.0961	0.0017	-3.145	-1.7043	0.9852	-0.019	-0.0026
PURI	< 0.0001	4.201	2.3423	0.0386	-2.068	-0.0717	0.0689	1.819	0.2385	0.0002	3.763	1.6282	0.1803	1.340	0.4196
RAYGADA	0.4263	0.795	0.4991	0.3103	-1.015	-0.0237	0.0295	2.177	0.4167	0.9926	-0.009	-0.0055	0.2910	1.056	0.2373
SAMBALPUR	0.9074	-0.116	-0.0545	0.2100	-1.254	-0.0645	0.6187	-0.498	-0.059	0.9852	0.019	0.0191	0.2074	1.261	0.1223
SONPUR	0.5547	-0.591	-0.3465	0.0499	-1.961	-0.0812	0.3768	-0.884	-0.1092	0.5119	-0.656	-0.316	0.8670	0.167	0.0231
SUNDARGARH	0.0112	-2.535	-1.3201	0.1121	-1.589	-0.0925	0.6960	0.391	0.0421	0.0058	-2.759	-1.4354	0.2008	1.279	0.1379





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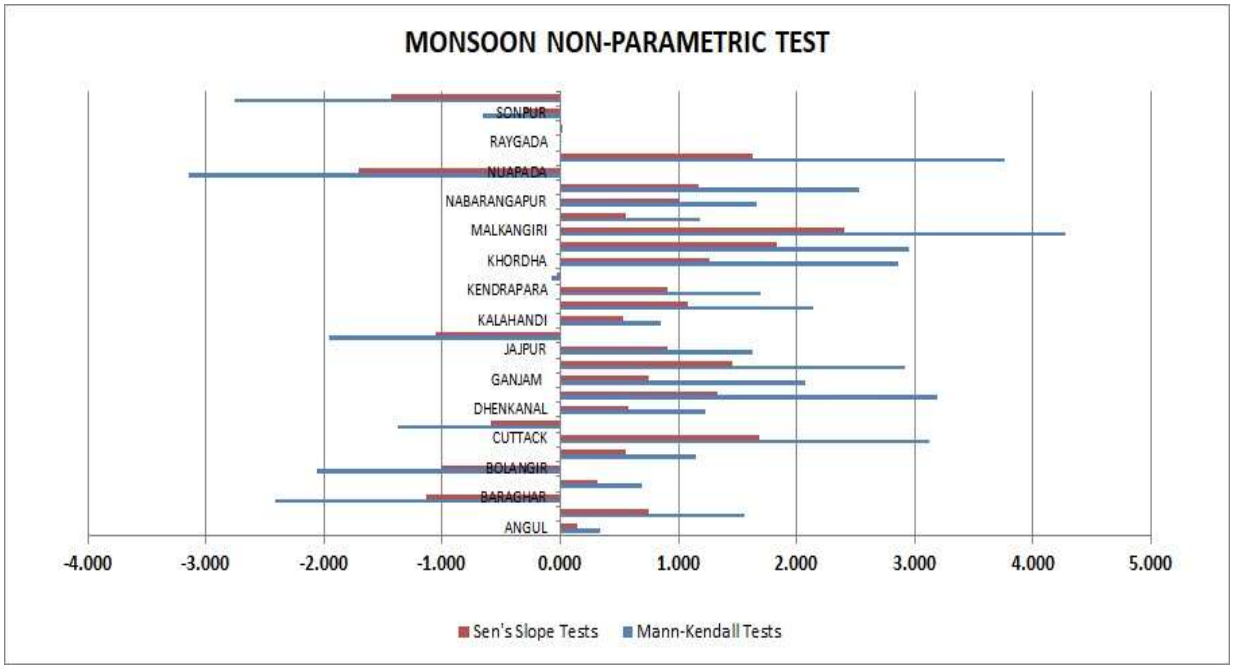

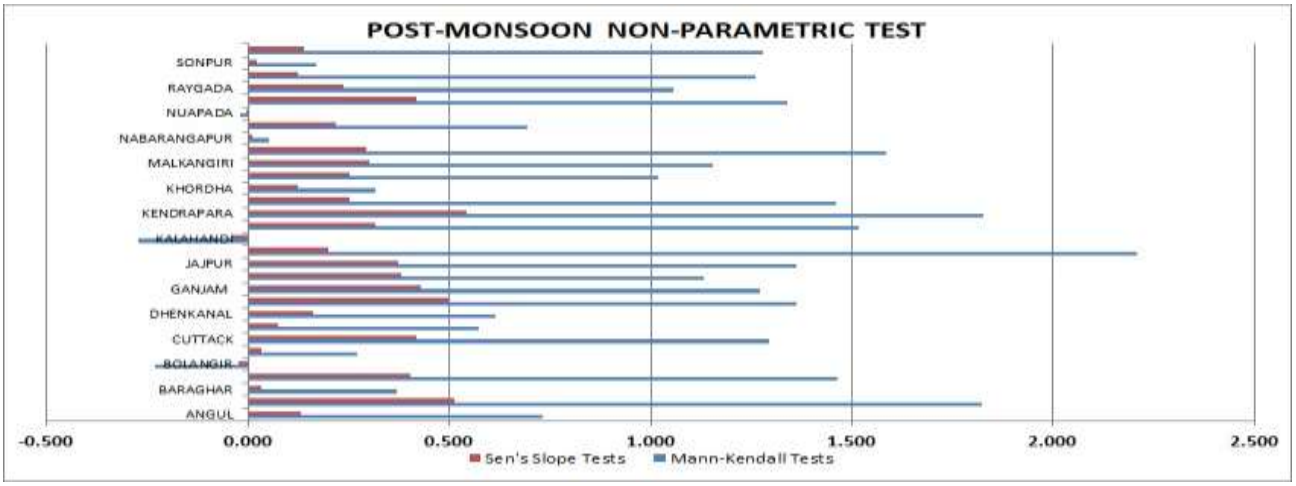

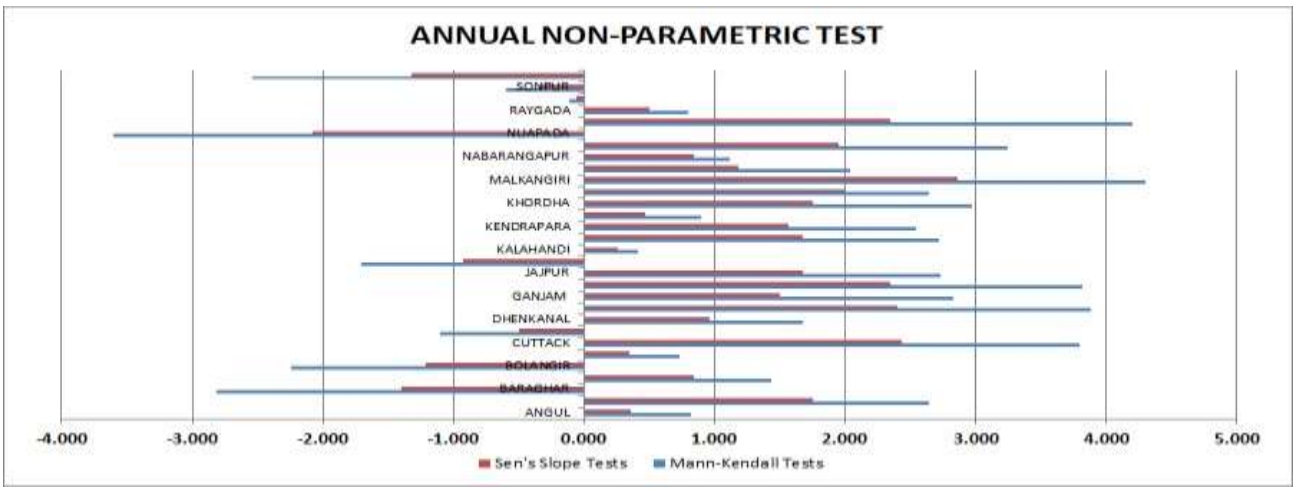

If we considered Annually rainfall trend, we found that Balasore, Baragarh, Bolangir, Cuttack, Gajapati, Ganjam, Jagatsinghpur, Jajpur, Kandhamal, Kendrapara, Khordha, Koraput, Malkangiri, Mayurbhanj, Nayagarh, Nuapada, Puri, Sundergarh districts indicates the presence of a trend in the series. The Bargarh, Boudh, Jagatsinghpur, Kalahandi, Kendrapara, Koraput, Malkangiri, Nuapada, Puri, Sonpur districts show the presence of a trend in the series in Winter.

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During the Pre-monsoon season, Cuttack, Gajapati, Ganjam, Jagatsinghpur, Jajpur, Kandhamal, Khordha, Nayagarh, Rayagada districts show the presence of trends in the observations. During the Monsoon season Baragarh, Bolangir, Cuttack, Gajapati, Ganjam, Jagatsinghpur, Jharsuguda, Kandhamal, KhordhaKoraput, Malkangiri, Nayagarh, Nuapada, Puri, Sundergarh districts show a trend in the series of observations. During the Post-monsoon season, we found that no districts showed any kind of presence of trend in the observations.

During the Annual Rainfall period, Bargarh, Bolangir, Deogarh, Jharsuguda, Nuapada, Sambalpur, Sonpur, Sunderghar districts show negative trends, except these all remaining districts show positive trends. Bargarh, Balangir, Nuapada, Sundergarh districts show significant negative trends. During, Winter Season all districts show negative trends. Bargarh, Boudh, Jagatsinghpur, Kalahandi, Kendrapara, Koraput, Malkangiri, Nuapada, Puri, Sonpur districts show significant negative trends in the series. During the Pre-monsoon season, Bargarh, Bolangir, Boudh, Deogarh, Kalahandi, Malkangiri, Nuapada, Sambalpur, Sonpur districts show non-significant negative trends, excepts these all districts show positive trends. During the Monsoon season, Bargarh, Bolangir, Deogarh, Jharsuguda, Keonjhar, Nuapada, Raygada, Sonpur, Sundergarh districts show negative trends, out of these Bargarh, Bolangir, JharsugudaNuapada, Sundergarh districts show significant negative trends. During the Post-monsoon season, Bolangir, Ganjam, Kalahandi, Nuapada districts show non-significant negative trends, except all districts show positive trends.

The estimated Sen's slope has been calculated for 30 districts of Odisha on an annual and four-season basis. Positive Sen's slope value indicates the rising trends of magnitude in the series and the Negative Sen's slope value indicates the decreasing trends of magnitude in the series. During Mann-Kendall's test results, we got some districts that show negative trends, these districts show negative trends in Sen's slope test as well. Mann-Kendall trend analysis has shown a negative trend, similar negative slope has been observed for the Sen's Slope and vice versa.

b.Trend analysis using Regression model

DISTRICT	ANNUAL		WINTER		PREMONSOON		MONSOON		POSTMONSOON	
	Y Value	R2 Value	Y Value	R2 Value	Y Value	R2 Value	Y Value	R2 Value	Y Value	R2 Value
ANGUL	0.3795x + 539.93	0.0042	-0.1285x + 286.45	0.0182	-0.0414x + 185.71	0.0007	0.3649x + 313.6	0.0052	0.1845x - 245.83	0.0104
BALASORE	1.8046x - 2000.9	0.0671	-0.0925x + 222.96	0.0078	0.2064x - 222.37	0.0082	1.0306x - 892.61	0.0323	0.6601x - 1108.9	0.0412
BARAGHAR	-1.0817x + 3416	0.036	-0.1111x + 241.03	0.0344	-0.1761x + 408.99	0.0271	-0.8762x + 2865.5	0.0283	0.0817x - 99.495	0.0062
BHADRAK	0.8569x - 220.61	0.0181	-0.1225x + 277.35	0.0157	0.1897x - 223.47	0.0093	0.266x + 561.35	0.0028	0.5237x - 835.82	0.0276
BOLANGIR	-0.8106x + 2880.9	0.0187	-0.0778x + 173.29	0.0193	-0.1334x + 336.14	0.0131	-0.6144x + 2325.9	0.0124	0.015x + 45.55	0.0001
BOUDH	0.7733x - 271.3	0.0166	-0.1579x + 336.95	0.0425	-0.2001x + 476.47	0.0189	1.0262x - 975.74	0.0348	0.1051x - 108.98	0.0044
CUTTACK	2.7989x - 4155.3	0.1506	-0.0611x + 153.6	0.004	0.3029x - 491.69	0.0372	2.1857x - 3307.2	0.1327	0.3714x - 509.98	0.0125
DEOGARH	-0.5407x + 2408.3	0.0082	-0.1281x + 284.99	0.0206	-0.068x + 219.97	0.0025	-0.4991x + 2121.3	0.009	0.1545x - 217.96	0.0124
DHENKANAL	0.837x - 325.11	0.0187	-0.1174x + 266.25	0.012	0.1024x - 83.414	0.0036	0.6324x - 237.01	0.0162	0.2196x - 270.93	0.0075
GAJAPATI	2.8392x - 4467.1	0.162	-0.0313x + 79.172	0.0038	0.7382x - 1343.6	0.1338	1.6241x - 2431	0.1112	0.5082x - 771.66	0.0202
GANJAM	1.6989x - 2189.8	0.0798	-0.0773x + 178.39	0.0116	0.2478x - 394.08	0.0291	0.9441x - 1054.4	0.049	0.5844x - 919.64	0.0247
JAGATSINGHAPUR	2.4914x - 3532.1	0.1309	-0.0956x + 216.62	0.0127	0.4316x - 756.35	0.0868	1.6877x - 2314.8	0.0898	0.4677x - 677.51	0.0178
JAJPUR	1.8174x - 2128.6	0.073	-0.0775x + 188.19	0.0061	0.3438x - 538.58	0.0339	1.1096x - 1099.1	0.0395	0.4415x - 679.15	0.0213
JHARSUGUDA	-0.6393x + 2657	0.0104	-0.0957x + 214	0.0235	-0.0127x + 83.489	0.0002	-0.8229x + 2871.3	0.02	0.2921x - 511.85	0.0694
KALAHANDI	0.8622x - 296.21	0.0149	-0.1013x + 216.05	0.0371	-0.2849x + 662.46	0.0296	1.2429x - 1267.9	0.0349	0.0054x + 93.206	1.00E-05
KANDHAMAL	2.6562x - 3946.3	0.1106	-0.0419x + 107.75	0.0039	0.2143x - 320.94	0.0174	1.9999x - 2918.1	0.0858	0.4839x - 814.96	0.0449
KENDRAPARA	1.4971x - 1458.8	0.052	-0.1498x + 324.48	0.0293	0.1265x - 125.32	0.0054	0.856x - 579.28	0.025	0.6644x - 1078.7	0.0374
KEONJHAR	0.9177x - 440.29	0.0207	-0.1494x + 336.69	0.0176	0.2082x - 272.56	0.0134	0.514x + 52.637	0.0092	0.3449x - 557.06	0.0333
KHORDHA	2.0053x - 2671.3	0.0887	-0.0923x + 213.37	0.0095	0.2669x - 432.07	0.0353	1.672x - 2395.1	0.1033	0.1586x - 57.589	0.0016
KORAPUT	2.9802x - 4512.5	0.1143	-0.1015x + 213.04	0.0544	-0.0481x + 215.6	0.0006	2.9676x - 4797.1	0.1339	0.1621x - 143.98	0.0042
MALKANGIRI	4.0998x - 6847.2	0.2419	-0.0523x + 113.12	0.0239	-0.1881x + 459.78	0.0174	4.075x - 7074.5	0.2573	0.2653x - 345.65	0.011
MAYURBHANJ	1.5161x - 1562.2	0.0546	-0.1627x + 364.8	0.0222	0.2812x - 385.25	0.0182	0.9609x - 820.19	0.0338	0.4367x - 721.53	0.0355
NABARANGAPUR	1.5482x - 1580.1	0.0325	-0.0548x + 123.75	0.0109	-0.0074x + 131.3	2.00E-05	1.6002x - 1935.4	0.0406	0.0103x + 100.29	2.00E-05
NAYAGARH	2.303x - 3275.5	0.1101	-0.0403x + 112.3	0.0019	0.3093x - 506.43	0.0398	1.7504x - 2532.6	0.1012	0.2836x - 348.75	0.0071
NUAPADA	-1.7789x + 4791.9	0.0789	-0.076x + 165.74	0.0222	-0.1597x + 388.11	0.0178	-1.5195x + 4117.9	0.0663	-0.0238x + 120.09	0.0003
PURI	2.8044x - 4304.5	0.1715	-0.0799x + 181.99	0.0111	0.1814x - 271.24	0.0199	2.1688x - 3388.4	0.1509	0.534x - 826.8	0.0254
RAYGADA	0.5313x + 235.74	0.0071	-0.0474x + 108.6	0.0122	0.1673x - 206.27	0.007	0.1942x + 615.03	0.0013	0.2172x - 281.63	0.01
SAMBALPUR	0.2861x + 805.92	0.002	-0.0918x + 209.54	0.0161	-0.0953x + 256.82	0.0062	0.2412x + 724.13	0.0017	0.232x - 384.57	0.0351
SONPUR	0.4529x + 378.72	0.0048	-0.1183x + 258.18	0.0282	-0.1556x + 377.75	0.0151	0.647x - 175.49	0.011	0.0797x - 81.72	0.0043
SUNDARGARH	-1.1328x + 3624.6	0.0344	-0.1344x + 296.34	0.0329	0.004x + 60.511	1.00E-05	-1.2253x + 3636.3	0.0467	0.2229x - 368.55	0.0337

It is evident from the above figures that Annual Rainfall has increased significantly for the districts of Angul, Balasore, Bhadrak, Boudh, Cuttack, Dhenkanal, Gajapati, Ganjam, Jagatsinghpur, Jajpur, Kalahandi, Kandhamal, Kendrapara, Keonjhar, Khordha, Koraput, Malkangiri, Mayurbhanj, Nabarangpur, Nayaghar, Puri, Rayagada, Sambalpur, Sonpur except for the districts of Baraghar, Bolangir, Deoghar, Jharsuguda, Nuapada, Sundergarhfor which a very weak decrease in Rainfall is observed. If we considered Winter season rainfall, we observed that all the districts show a very weak decrease in rainfall. During the Pre-monsoon season Angul, Bargarh, Bolangir, Boudh, Deoghar, Jharsuguda,

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 10| Issue: 3| March 2024|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2024: 8.402 || ISI Value: 1.188

Kalahandi, Koraput, Malkangiri, Nabarangpur, Nuapada, Sambalpur, Sonpur districts observed a decrease in rainfall, except these districts all other remaining districts of Odisha observed an increasing Rainfall during Pre-monsoon season. In the Monsoon season Baraghar, Bolangir, Deogarh, Jharsuguda, Nuapada, Sundergarh indicate a decrease in Rainfall, remaining districts of this season indicate an increase in Rainfall. During the Post-monsoon season only one district, Nuapada shows a decrease in Rainfall, and other districts observed an increase in Rainfall.

During Annual rainfall, Malkangiri districts show the highest increase in Rainfall (4.0998 mm) and have increased by 487.876 mm during the last 119 years. Nuapada district observed the highest decrease in rainfall by 211.6891 mm during the last 119 years. During Winter, all districts observe a decrease in rainfall. Mayurbhanj district observed the highest decreased in rainfall by 19.3613 mm during the last 119 years. During the Pre-monsoon season, Gajapati districts show the highest increase in rainfall (0.7382 mm) and have increased by 87.8458 mm during the last 119 years. Sonpur district observed the highest decrease in rainfall by 18.5164 mm during the last 119 years. In the Monsoon season, Malkangiri districts observed the highest increase in rainfall (4.075 mm) and have increased by 484.925 mm during the last 119 years. Nuapada district observed the highest decreased in rainfall by 180.8205 mm during the last 119 years. In the Post-monsoon season, Balasore districts observed the highest increase in rainfall (0.6601 mm) and have increased by 78.5519 mm during the last 119 years. Nuapada districts observed the highest decreased in rainfall by 2.8322 mm during the last 119 years.

CONCLUSION

The average annual normal rainfall over Odisha from 1901 to 2019 is 1259.15 mm, with a standard deviation of 231.61 mm. It is found that the monsoon season has a maximum contribution to annual rainfall, and it does not have any strong trend in nature over the study period by using two techniques. However, it was also observed that there is a great seasonal variation in rainfall trends. The percentage deviations of season rainfall were found to be more for dry periods (post-monsoon and pre-monsoon) than for monsoon season. The trend analysis shows that except in winter (which shows negative trends) overall trends show an increment in rainfall.

Balasore district has more rainfall in the annual and pre-monsoon season and second highest in winter (Mayurbhanj has the highest rainfall in this season).Gajapati district has the lowest rainfall in the annual and monsoon season. Jharsuguda district has the lowest rainfall in the Pre-monsoon season and Post-monsoon season. Sundergarh district has high rainfall during the monsoon season and Khordha district has high rainfall during the Post-monsoon season. Because of high rainfall in the Khordha district observes urban flood and water-logging problems occurring in this area during the monsoon season. During, Annual rainfall, Malkangiri, and Koraput district shows least stable (fluctuate more). During Winter Nuapada, during Pre-monsoon season Gajapati, during monsoon season Malkangiri, during Post-monsoon season Jharsuguda shows least stable in rainfall. During the Pre-monsoon season Balasore district shows very much stable rainfall.

The Mann-Kendall Test represents both positive and negative trends in the area although not much significant. Rainfall varies in different seasons for different years, which are evident in the graphs. Only during the post-monsoon season, all districts observed a non-significant trend During annual rainfall, Malkangiri districts show an increasing trend, and Nuapada districts (-3.6) show a decreasing trend. During Winter all districts show a decreasing trend, Boudh districts observed more decreasing trends as compared to other districts. During the Pre-monsoon season, Gajapati districts (3.9) show an increasing trend, and Kalahandi districts (-1.3) show a more decreasing trend. During the Monsoon season, Malkangiri (4.2) shows an increasing trend, and the Nuapada districts (-3.1) show a decreasing trend. During the Post-monsoon season, Jharsuguda districts (2.2) show a high increasing trend and only three districts show decreasing trends these are Nuapada (-0.01), Kalahandi and Balangir districts. Sen's Slope is also indicating increasing and decreasing magnitude of slope in correspondence with the Mann-Kendall test values.

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ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 10| Issue: 3| March 2024|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2024: 8.402 || ISI Value: 1.188

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