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SPATIO-TEMPORAL TREND ANALYSIS OF RAINFALL OF COASTAL DISTRICTS OF ODISHA

Mr. Suraj Kumar Behera

Mr. Suraj Kumar Behera, Guest Lecturer in PG Department of Geography, MPC Autonomous College, Takhatpur, Baripada, Odisha

ABSTRACT

In the recent period the most important challenge faced by researchers is to have a better knowledge about climate change at a regional level. The change in climate at local or regional level is unequal and it has a localized intensity. Therefore it is identified at a local scale. Temperature and Precipitation are the two important variables of climate, which are more responsible for climate change in local level and required to give more concerned about it. Here we take one climatic variables i.e. Rainfall for our study in the 7 Coastal districts of Odisha. The state of Odisha is located in the east coast of Indian peninsula. Most of the agricultural region of odisha is located in the coastal belt of Odisha. Agriculture plays a vital role in the economy of Odisha, which is highly influenced by rainfall. Any change in pattern of rainfall cause by climate change can adversely affect the production of crop. Therefore in the current study, an attempt has been made to observe spatio-temporal rainfall change and its trend over a period of 119 years (i.e. 1901-2019). For this study we used the non-parametric trend analysis techniques, namely Mann kendall test and Sen's slope estimator for observing the trend direction and magnitude of the change over the 7 coastal districts of odisha i.e. Balasore,Bhadrak,Ganjam,Jagatsinghpur, Kendrapada, Khorda and Puri. The observed variation in rainfall revealed that, the monsoon season has maximum contribution to annual rainfall and it does not have any strong trend over the coastal areas of Odisha in study period of time. The outcomes of the study gives information on rainfall trends and impact of climate change in coastal districts of Odisha which will be helpful for a water resources manager in the planning and management of water resources for sustainable development and particularly for the benefits of agriculture of coastal odisha.

KEYWORDS: *Climate Change, Coastal Odisha, Trend Analysis, Rainfall, Regression line, Mann-Kendall (MK) Test and Sen's Estimator*

INTRODUCTION

Variation in Rainfall will be one of the vital factors for determination of impacts of climate change. It is necessary to give instant and systematic attention in the variation of rainfall because it affects the agricultural production and availability of water for drinking purpose (Dore, 2005). Change in the pattern of rainfall has impact on availability of fresh water and agriculture allied sector of the region of Asia Pacific (Cruz et al., 2007). In the last few decades we observe frequently the impact of extreme events like Droughts and Floods, it is due to the result of growth of population, increased in urbanization and increased in the intensity of rainfall. To observe the effect of climate change several studies have been conducted for the analysis of spatial and temporal variations in rainfall. 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 the report of Intergovernmental Panel on Climate change (IPCC, 2007) in the all over Asia the seasonal, annual and spatial variation in precipitation trends were observed during past few decades. It is found that precipitation has increased in the latitudinal extension of 10˚N to 30˚N for few decades, it starts from the year 1900 onwards and a decrease trend has noticed after the year of 1970. A decreasing trend of rainfall was found in the latitudes of 10˚N to 10˚S. But the tropical and sub-tropical regions were observing increased in dry conditions due to decrease in rainfall from 1970. During summer season increasing rainfall was observed in eastern part of Australia in 1950s and this trend is continued for few decades which is observed in initial observation (Nicholls and Lavery, 1992).

Climate change has significant impact on the coastal areas population and agricultural production. According to India's National Communication (NATCOM) to the United Nations Framework Convention on Climate Change (UNFCC) report (2004), variety of impacts are expected in the coastal areas due to climate change, it include loss of the land property, displacement of population, increased in flood condition in low-lying areas, agricultural impacts (like, loss of yield and employment) and impacts on coastal aquaculture. Change in the Climate is often a concern for the coastal Odisha of India, because every year cyclones occurs in the Bay of Bengal which affects the coastal areas of Odisha. We observed the impact of 1999 tropical super cyclones devastating power which impact on the coastal agricultural system of Odisha.

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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.

Therefore, the major aim of this research is to analyze the variability in the Rainfall of 7 coastal districts 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 7 districts i.e.
Balasore,Bhadrak,Ganjam,Jagatsinghpur,Kendrapada,Khorda and Puri of coastal Odisha during 1901-2019 at regional level. In this study, we can get knowledge about the rainfall patterns of coastal Odisha, which will help us for better management of agriculture in coastal districts of Odisha, hydropower generation, and other water-related activities.

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 in the coastal districts of Odisha, which needed 200cm of rainfall for cultivation.

The mean annual temperature of the state is 26.89˚C with average annual maximum and minimum of 32.56˚ C and 21.30˚ C respectively. The temperature in Odisha rises to very high in the months April and May . Warm is occurring throughout the year in the western districts with maximum temperature lies between 40-46˚C. Whereas the climate in the coastal districts are highly humid and sticky. Due to tropical monsoon hydrology and change in climatic variables, the coastal region of state is facing floods, draughts and cyclones in almost every year with different intensity which is adversely affecting the agricultural production in the coastal region of Odisha.

DATA AND METHODOLOGY

Monthly rainfall data for 7 coastal districts of Odisha from 1901 to 2019 for 119 years is considered for analysis of trend, variability, and mean rainfall patterns. 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). For identification of the spatial pattern, mean rainfall, and variability, and observed trends, we have used district rainfall series and results have been brought out annually and seasonally. Statistical methods, such as regression analysis and coefficient of determination R^2 (Deshmukh,2013) are used. The non-parametric tests such as the MK test and Sen's Slope estimator test have been used in this study for trend analysis.

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.

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RESULTS AND DISCUSSION

a. MEAN AND COEFFICIENT OF VARIATION

COASTAL DISTRICTS	ANNUAL		WINTER		PRE-MONSOON		MONSOON		POST-MONSOON	
	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV
BALASORE	1536.2	15.6	41.7	86.4	182.1	43.1	1127.4	17.6	185	60.6
BHADRAK	1459	15	37.2	90.7	148.4	45.6	1082.7	16	190.7	57
GANJAM	1140.1	18.2	26.8	92.2	91.6	54.7	796	18.5	225.8	56.8
JAGATSINGHAPUR	1351.1	17.6	29.2	100.2	89.5	56.5	993.1	19.6	239.2	50.6
KENDRAPARA	1475.6	15.4	30.9	97.6	122.6	48.3	1098.6	17.0	223.4	53
KHORDHA	1259	18.5	32.5	100.6	91	53.8	882.1	20.3	253.4	53.7
PURI	1192.1	19.6	25.4	103.3	84.3	52.6	862.5	22.3	219.9	52.5

The table gives the rainfall statistics for the coastal districts of Odisha for the four seasons i.e. Winter season (Jan-Feb), Pre-monsoon Season(March-May), Monsoon Season (June-Sept), Post-monsoon season(Oct-Dec), and Annual. It shows the spatial pattern of the Mean and Coefficient of Variation. Higher the mean value of the district shows the district receives more rainfall and lower the mean value it shows that the district receives less rainfall. We can see that the districts viz. Balasore, Bhadrak receives the highest rainfall, and the Ganjam districts receive the lowest rainfall during the entire year (annual).

Higher the Coefficient of variation indicates the variation is least stable and lower in the CV indicates the variation is very much stable. The coefficient of variation of rainfall is very high in Winter (values vary from 86.4-103.3). The coefficient of variations of the Pre-monsoon season is higher than the coefficient of variation of Monsoon season and Post-monsoon season, respectively. The Annual values of the coefficient of variation are very low, it varies between 15.0-19.6. From the above, we concluded that in Winter Rainfall variation is more, which means it is very much unstable in comparison to another season. But the CV is very much low in annual value, which means the annual rainfall does not fluctuate or varies more (it is stable). The district viz. Balasore, Bhadrak showing a low Annual coefficient of variation, on the other hand, Kendrapara showing high Annual CV.

b. Trend Analysis using Non–Parametric tests

COASTAL DISTRICTS	ANNUAL			WINTER			PRE-MONSOON			MONSOON			POST-MONSOON		
	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
BALASORE	0.008	2.64	1.75	0.30	-1.01	-0.06	0.26	1.11	0.29	0.12	1.55	0.75	0.06	1.82	0.51
BHADRAK	0.15	1.43	0.84	0.18	-1.33	-0.08	0.21	1.23	0.23	0.49	0.68	0.31	0.14	1.46	0.40
GANJAM	0.004	2.82	1.49	0.27	-1.09	-0.04	0.01	2.45	0.32	0.03	2.07	0.75	0.20	1.27	0.43
JAGATSINGHAPUR	0.0001	3.81	2.34	0.05	-1.95	-0.09	0.003	2.89	0.39	0.003	2.91	1.45	0.25	1.13	0.38
KENDRAPARA	0.01	2.54	1.56	0.009	-2.58	-0.13	0.34	0.95	0.15	0.09	1.69	0.90	0.06	1.82	0.54
KHORDHA	0.003	2.97	1.75	0.18	-1.31	-0.04	0.03	2.15	0.31	0.004	2.85	1.26	0.75	0.31	0.12
PURI	0.0001	4.20	2.34	0.03	-2.06	-0.07	0.06	1.81	0.23	0.0002	3.76	1.62	0.18	1.34	0.41

If we considered Annual rainfall trend, we found that Balasore, Ganjam, Jagatsinghpur, Kendrapara, Khordha, Puri districts indicates the presence of a trend in the series. The Jagatsinghpur, Kendrapara, Puri districts show the presence of a trend in the series in Winter. During the Pre-monsoon season, Ganjam, Jagatsinghpur, Khordha districts show the presence of trends in the observations. During the Monsoon season Ganjam, Jagatsinghpur, Khordha, Puri 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, all these districts show positive trends. During, Winter Season all districts show negative

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trends. Jagatsinghpur, Kendrapara, Puri districts show significant negative trends in the series. During the Pre-monsoon season, all these districts show positive trends. During the Monsoon season, all districts show significant positive trend. During the Post-monsoon season, Ganjam districts show non-significant negative trends, except all districts show positive trends.

The estimated Sen's slope has been calculated for 7 coastal 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 BY REGRESSION METHOD

COASTAL DISTRICTS	ANNUAL		WINTER		PRE-MONSOON		MONSOON		POST-MONSOON	
	Y value	R2 value	Y value	R2 value	Y value	R2 value	Y value	R2 value	Y value	R2 value
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
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
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
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
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
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

It is evident from the above tables that Annual Rainfall has increased significantly for the districts of Balasore, Bhadrak, Ganjam, Jagatsinghpur, Kendrapara, Khordha, Puri for 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, all districts observed a increase in rainfall. In the Monsoon season all these coastal districts of this season indicate an increase in Rainfall. During the Post-monsoon season also all district shows a increase in Rainfall.

During Annual rainfall, Puri districts show the highest increase in Rainfall (2.8044 mm). Bhadrak district observed the higest decrease in rainfall. During Winter, all districts observe a decrease in rainfall. During the Pre-monsoon season, Kendrapara districts show the highest increase in rainfall during the last 119 years. Jagatsinghapur district observed the highest decrease in rainfall during the last 119 years. In the Monsoon season, Puri districts observed the highest increase in rainfall during the last 119 years. Ganjam district observed the highest decreased in rainfall during the last 119 years. In the Post-monsoon season, Khorda districts observed the highest increase in rainfall during the last 119 years. Kendrapara districts observed the highest decreased in rainfall during the last 119 years.

CONCLUSION

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. However, it was also observed that there is a great seasonal variation in rainfall trends. The trend analysis

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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. 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 the Pre-monsoon season Balasore district shows very much stable rainfall.

It is observed that the year 1956 is a change point year, where high rainfall is found in all most every district of Odisha during the Annual and Monsoon season. One other changing point year is 2006, where maximum districts observed high rainfall during annual and monsoon season. Another interesting observation is that if rainfall is high during a year in a district within two years, it decreases.

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. Only during the post-monsoon season, all districts observed a non-significant trend. Sen's Slope is also indicating increasing and decreasing magnitude of slope in correspondence with the Mann-Kendall test values.

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