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Spatio-temporal analysis of rainfall distribution and its variability in mid central table land zone of Odisha

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Abstract

The study aims to analyse the spatial- temporal rainfall distribution and its variability in mid central table land zone of Odisha. Annual, seasonal, monthly rainfall as well as the probability of rainfall was computed by using 'Weather cock' software. To detect trends in annual and seasonal rainfall 'MMKY' package in 'R studio' software was used. Rainfall data of thirty three year (1991 to 2023) was collected from special Relief Commissioner (SRC), Govt. of Odisha for the purpose of block wise rainfall analysis in the study area. Present study reviled that the average annual rainfall in the mid-central table land zone was 1371mm. Among the two districts, Dhenkanal district recorded the maximum rainfall of 1423mm. The monsoon season accounted for the largest portion of the total rainfall, contributing between 72% and 86%. Most blocks are experiencing a decreasing trend in annual and southwest monsoon rainfall and increasing trend in post-monsoon and winter rainfall across most blocks in this zone. The blocks facing a decreasing trend should explore alternative strategies such as irrigation. Furthermore, the rise in post-monsoon and winter rainfall across most blocks in this zone highlights the significance of cultivating *Rabi* crops. Leveraging long-term regional weather data to assess the impacts of climate change, such as extreme weather patterns and their effects on the local environment, requires urgent focus for better agricultural planning and management.

Keywords: Rainfall, climate change, CV, SW monsoon, trend

1. Introduction

In the monsoonal climatic region, there is a noticeable seasonal fluctuation in climatic factors, particularly in rainfall (Rathore *et al.* 2013) ^[1]. In India, approximately 80% of the annual rainfall comes from the southwest monsoon (Lal 2003) ^[2]. The spatial and temporal variations in monsoonal and annual precipitation are well recognized, and this year-to-year fluctuation in monsoon rainfall significantly affects agricultural production. Among climatic factors, precipitation is one of the most unstable, showing marked spatial and temporal differences over daily, decadal, and longer periods (Juan-Carlos *et al.* 2009) ^[3]. Krishna Kumar *et al.* (2008) ^[4] examined the temporal (monthly, seasonal, and annual) rainfall trends in Kerala, India, throughout the twentieth century and observed a notable decline in rainfall during the southwest monsoon, alongside an increase during the post-monsoon period. In order to study rainfall characteristics, Chakraborty *et al.* (2013) ^[5] conducted a study on the spatial and temporal variability of rainfall within the Seonath sub-basin in Chhattisgarh State, India, over a period of 49 years (from 1960 to 2008). They employed various statistical methods. The Modified Mann-Kendall (MMK) test (a non-parametric method) and Spearman's rho test (a parametric method) were utilized to identify trends. Sen's slope method was used to determine the magnitude of the trends. Change points were identified using the CUSUM and cumulative deviations tests. For variability analysis, the Coefficient of Variation was employed. Both tests revealed a downward trend in the annual and seasonal rainfall series across the entire river basin. Mondal *et al.* (2002) ^[6] utilized the Mann-Kendall test to assess the shifting patterns of rainfall in a river basin located in the coastal area of Odisha.

The objective of this study to analyse the spatial- temporal rainfall distribution and its variability in mid central table land zone of Odisha. The information will help the farmers and policy makers in planning agriculture objectively for the region.

2. Materials and Methods

2.1 Study Area

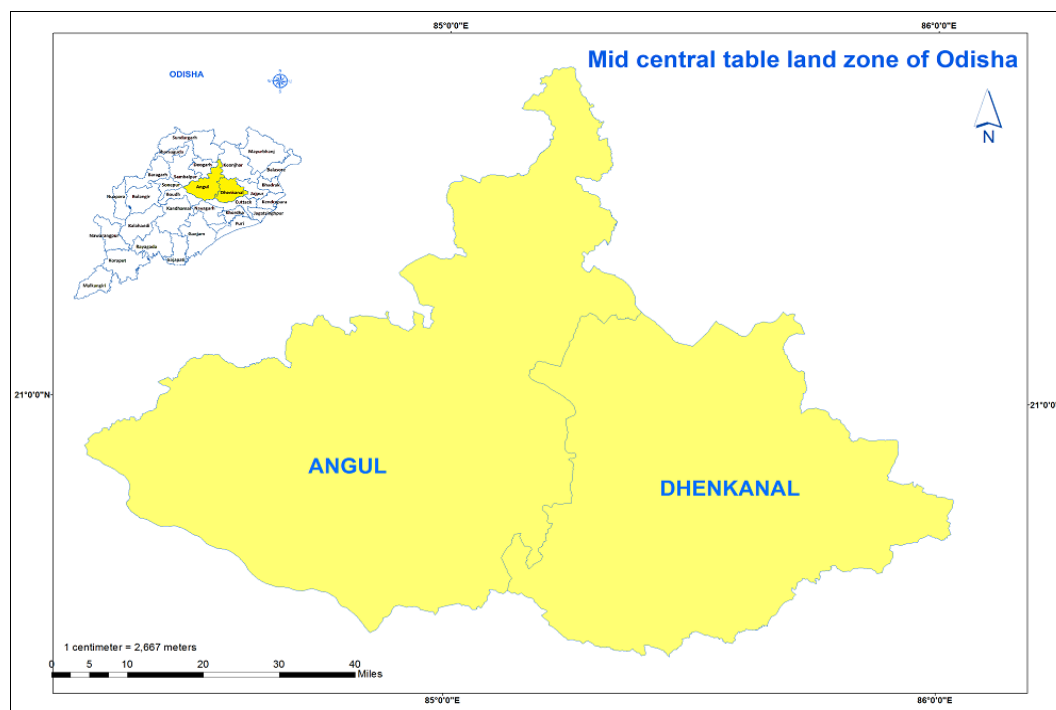


Fig 2.1: Mid central table land agroclimatic zone of Odisha.

The study has been carried out in the Mid Central Table Land Zone in the state of Orissa, India. It is geographically situated between 80.0°E longitude and 20.0°N latitude and covers districts of Angul, Dhenkanal, part of Cuttack and Jajpur. The zone experiences a warm and humid climate. The average annual rainfall of this zone is 1426.6 mm, of which 86.5% occurs during the southwest monsoon season. However, there is significant variation in rainfall from year to year. Mean maximum temperature is 38.7°C, and means minimum temperature is 14.0°C. The soils in the zone are alluvial, red, lateritic, and mixed red and black. The Dhenkanal District consists of eight blocks: Bhuban, Dhenkanal Sadar, Gondia, Kamakhyanagar, Hindol, Kanakadahad, Parjang, and Odapada. Similarly, the Angul district also has eight blocks: Angul, Athmallik, Banarpal, Chhendipada, Kaniha, Kishorenagar, Pallahada, and Talcher.

2.2 Rainfall & rainy days analysis

Rainfall data of thirty three year (1991 to 2023) was collected from special Relief Commissioner (SRC), Odisha for the purpose of rainfall analysis in the study area. The analysis was conducted for each block of Dhenkanal and Angul districts. Annual, seasonal, monthly rainfall as well as the probability of rainfall was computed using the software known as 'Weather cock'. This software includes 26 modules that pertain to agro-climatic factors. A day is considered as a rainy day if the rainfall is equal to or exceeds 2.5 mm, as defined by the India Meteorological Department for the Indian region.

2.3 Trend analysis

The daily rainfall data at block level were subjected to non-parametric Modified Mann-Kendall Test using 'mmky' package in 'R studio' software to detect trends in annual and seasonal

rainfall. The modified Mann-Kendall test (Yue and Wang, 2004) [7] was used as it addresses the issue of serial correlation, which exists in time series data, by variance correction approach.

3. Results and Discussion

3.1 Annual Rainfall and rainy days

The average annual rainfall for the Mid Central Table Land zone was 1371 mm. Among the two districts, Dhenkanal district recorded the highest rainfall of 1423 mm (Table 3.1). The annual rainfall variability ranges from 15% to 30%. The average number of rainy days in this zone is 64 days.

The average annual rainfall in Angul district is 1318 mm. The variability in annual rainfall across the district ranges from 15% to 30%. The highest rainfall was recorded in Pallhada block of 1791 mm, while Chhendipada had the lowest of 1137 mm. The blocks that received rainfall exceeding the district's average include Athmallik, Kishorenagar, and Pallahada. The highest number of rainy days, 73 days, was observed in Pallahada, whereas Banarpal and Chhendipada blocks experienced the lowest number of rainy days, with a total of 58.

The mean annual rainfall of Dhenkanal district was found to be 1423.2 mm. There is significant variability in rainfall at the block level. Hindol block recorded the highest rainfall of 1649.11 mm, while Parjang received the lowest rainfall of 1246.01 mm. Variability of the district annual rainfall was 18% to 27%. Consequently, blocks with a coefficient of variation (CV) of less than 25% can be considered as highly dependable rainfall. Except Kamakhyanagar all 7 blocks that fall into this category. In contrast, Kamakhyanagar Block exhibits a CV above the threshold, suggesting significant variability in the rainfall amounts they receive across different years. Hindol Block recorded the maximum number of rainy days of 72, while Parjang had the minimum with 59 days.

Table 3.1: Block mean annual rainfall with S.D. and CV of Angul & Dhenkanal districts

District	Blocks	Mean (mm)	SD	CV (%)	No. of rainy days
Angul	Angul	1294	189	15	66
	Athmallik	1406	381	27	60
	Banarpal	1172	276	24	58
	Chhendipada	1137	256	23	58
	Kaniha	1174	349	30	59
	Kishorenagar	1382	362	26	63
	Pallahada	1791	501	28	73
	Talcher	1192	340	29	61
Angul district average		1318	332	25	62
Dhenkanal	Bhuban	1447	351	24	65
	Dhenkanalsadar	1439	293	20	68
	Gondia	1358	302	22	63
	Hindol	1649	374	23	72
	Kamakhyanagar	1480	409	28	67
	Kankadahad	1494	281	19	69
	Odapada	1273	304	24	62
	Parjang	1246	291	23	59
Dhenkanal district average		1423	326	23	66

3.2 Monthly rainfall

In both the districts i.e. Angul and Dhenkanal, July received the highest amount of rainfall (334 & 337 mm), followed by August (331mm& 333mm) and September month (222mm& 239mm). The least rainfall occurred in the month of December (8 mm). August and September exhibited the least variability of 7-9%, whereas December showed the highest variability of 27-35% (Table 3.2 & 3.3).

Table 3.2: Block mean monthly rainfall with SD and CV (%) for Angul district

Block	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Angul	14	13	23	37	82	182	305	291	215	106	17	9
Athmallik	12	12	18	27	50	191	382	385	236	79	9	6
Banarpal	9	6	15	22	62	163	279	286	208	103	13	6
Chhendipada	8	9	13	28	72	166	261	268	203	90	12	8
Kaniha	10	10	12	18	52	167	305	289	202	90	11	7
Kishorenagr	12	11	12	20	49	192	384	387	226	76	7	7
Pallahada	16	13	19	34	83	300	459	464	260	120	10	13
Talcher	12	9	18	21	68	154	297	278	224	91	12	8
Mean	12	10	16	26	65	189	334	331	222	94	11	8
SD	3	2	4	7	14	47	67	71	20	15	3	2
CV	23	22	24	26	21	25	20	22	9	16	27	27

Table 3.3: Block mean monthly rainfall with SD and CV (%) for Dhenkanal district

Block	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bhuban	14	14	17	36	105	204	308	355	251	122	16	7
Dhenkanal sadar	12	11	16	33	94	198	334	335	237	144	17	7
Gondia	12	8	16	38	99	208	310	302	227	116	18	7
Hindol	15	13	28	46	105	213	385	344	285	178	24	15
Kamakhyanagar	13	10	17	41	95	202	363	352	242	119	17	8
Kankadahad	21	12	18	35	99	237	359	354	240	101	11	9
Odapada	12	9	16	22	62	166	326	317	208	115	13	8
Parjang	15	8	12	20	73	164	312	301	221	100	16	5
Mean	14	11	17	34	92	199	337	333	239	124	17	8
SD	3	2	5	9	16	24	29	23	23	26	4	3
CV	21	21	26	26	17	12	9	7	10	21	23	35

3.3 Seasonal Rainfall

In Angul district, approximately 77% of the total annual precipitation comes from the South West monsoon. The average rainfall during the South West monsoon in the district is 993mm,

with a standard deviation of ± 181 mm. The Pallahada block received the highest rainfall (1483 mm), while the Chhendipada block experienced the lowest (817 mm) during the monsoon season. The least amount of precipitation was noted in winter season. In the post-monsoon season, the variability in rainfall ranged from 70% to 129%, whereas in the summer season, it fluctuated between 42% and 77% (Table 3.4).

The average rainfall during the SW monsoon in Dhenkanal district was 1107 mm with a variation of ± 269 mm. The highest recorded monsoon rainfall was in Hindol block, which received 1227 mm, while Parjang block experienced the lowest with 998 mm. Nearly 78% of the total annual rainfall took place during the SW monsoon (Table 4). Consequently, it is evident that the SW monsoon represents a significant portion of rainfall distribution compared to other seasons. The variability of rainfall during the SW monsoon ranged from 18% to 29%. The least amount of rainfall recorded was 25 mm during winter, although this season exhibited the highest variability at 137%. During the post-monsoon period, rainfall variability ranged from 71% to 93%, while it was between 58% and 84% in the summer season (Table 3.5). The coefficient of variation for seasonal rainfall, except South West monsoon, exceeds the threshold of 50% for seasonal rainfall.

Table 3.4: Block seasonal rainfall with SD and CV (%) for Angul district

BLOCK	Monsoon			Post-monsoon			Winter			Summer		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Angul	993	181	18	132	93	70	27	30	112	142	83	59
Athmallik	1193	371	31	93	83	89	24	33	136	96	73	76
Banarpal	936	229	25	121	88	72	15	25	171	100	74	74
Chhendipada	817	244	30	35	45	129	23	29	128	263	111	42
Kaniha	963	300	31	109	93	86	20	30	145	82	59	72
Kishorenagar	1190	368	31	89	65	72	22	30	135	80	62	77
Pallahada	1483	471	32	143	105	73	28	42	148	137	73	53
Talcher	953	288	30	111	78	70	21	34	159	107	63	59
District Average	993	181	18	132	93	70	27	30	112	142	83	59

Table 3.5: Block mean seasonal rainfall with SD and CV (%) for Dhenkanal district

BLOCK	Monsoon			Post monsoon			Winter			Summer		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Bhuban	1117	292	26	145	102	71	27	40	147	158	104	66
Dhenkanalsadar	1104	260	24	168	143	85	23	27	115	143	83	58
Gondia	1046	242	23	140	114	82	20	28	141	152	99	65
Hindol	1227	279	23	217	193	89	27	31	114	178	103	58
Kamakhyanagar	1159	303	26	144	124	86	23	30	130	153	107	70
Kankadahad	1188	216	18	121	86	72	33	55	170	152	92	60
Odapada	1017	290	29	135	126	93	21	26	124	99	73	73
Parjang	998	272	27	120	98	81	23	36	157	105	88	84
District Average	1107	269	32	149	123	82	25	34	137	143	94	67

3.4 Probability of annual rainfall

Analyzing rainfall probabilities provides a better scope for predicting the minimum assured rainfall, which helps in crop planning. The quantities of rainfall corresponding to various probability levels (10-90%), referred to as assured rainfall, have been calculated for each standard week using the Incomplete Gamma Distribution model. This research involved a probability analysis of annual rainfall at the block level, focusing on three probability thresholds: 90%, 75%, and 50%.

For Angul district, Expected rainfall at 90% probability level was found to be above 1000 mm in two blocks Angul and Pallahara. At 75% probability, rainfall was above 900 mm in all blocks. All blocks receive more than 1100 mm rainfall at 50% probability (Fig 3.1).

The analysis of the incomplete gamma distribution for rainfall revealed that six blocks recorded a 90% dependable rainfall of less than 1100 mm, with the exceptions of Hindol block (1198.7

mm) and Kankadahad block (1144.9 mm). The lowest amount of 90% probable rainfall was observed in Odapada block at 885.6 mm. For a 75% probability, rainfall exceeded 1300 mm in one block only, namely, Hindol (1388.8 mm). In contrast, Odapada and Parjang blocks had rainfall below 1100 mm. At a 50% probability level, all blocks had rainfall exceeding 1200 mm, with Hindol block recording the highest at 1622.7 mm and Parjang block the lowest at 1224.7 mm (Fig 3.2).

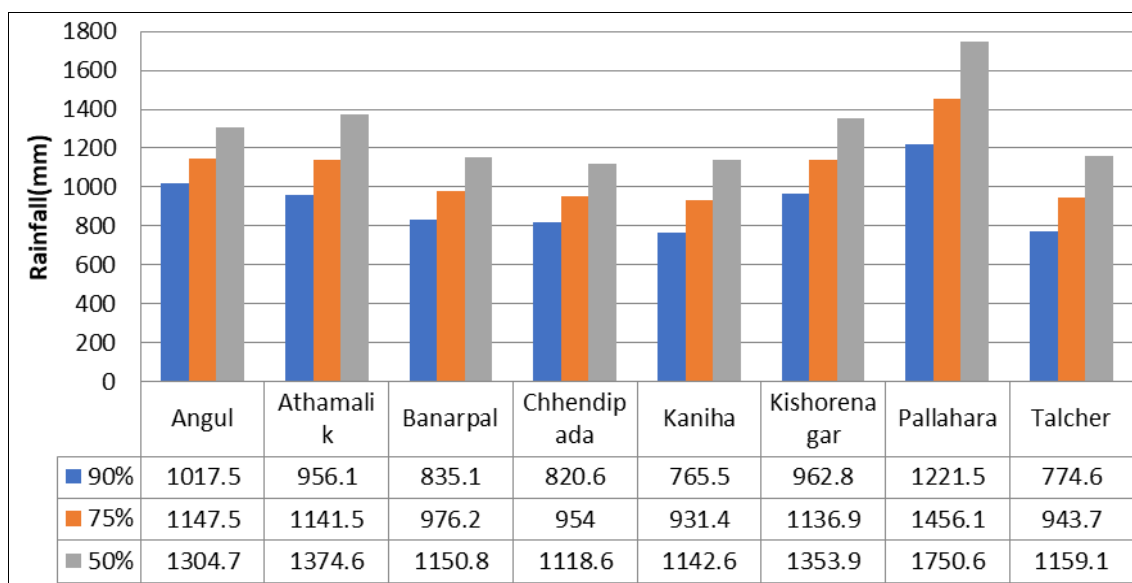


Fig.3.1: Dependable Rainfall of Angul district at 90%,75% & 50% probability.

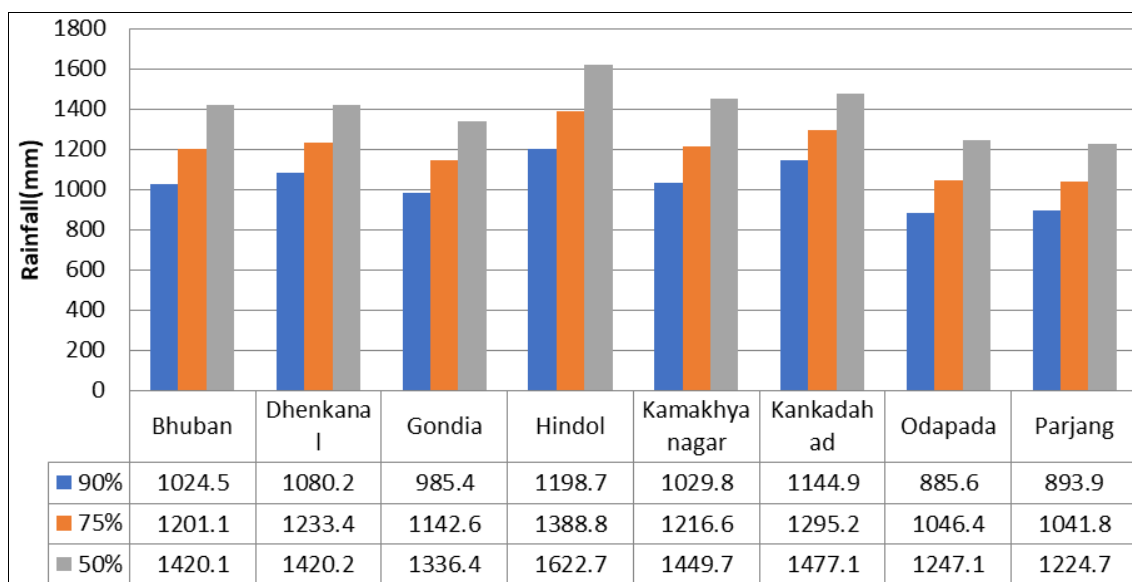


Fig.3.2: Dependable Rainfall of Dhenkanal district at 90%,75% & 50% probability.

3.5 Annual and Seasonal rainfall trend

The rainfall data at the block level for Angul and Dhenkanal districts over a period of 33 years (1991–2023) were subjected to Modified Mann-Kendall Test using ‘mmky’ package in ‘R studio’ software to identify trends in both annual and seasonal rainfall. The findings from the Modified Mann-Kendall test are summarized in table 3.6 & 3.7.

In the Angul district, among the 8 blocks, Banarpal, Chhendipada, and Talcher exhibited a significant increasing trend in annual and Southwest Monsoon rainfall, while Kaniha, Kishorenagar, and Pallahada showed a significant decreasing

trend. All blocks experienced an increasing trend in rainfall during the post-monsoon and winter seasons. During the summer season, all 6 blocks except for Chhendipada and Pallahada showed an increasing trend in rainfall.

In the Dhenkanal district, the Hindol, Bhuban, and block showed a significant increasing trend in annual rainfall. Conversely, a significant decreasing trend in annual rainfall was detected in the Odapada and Parjang blocks. During the southwest monsoon season, all five blocks, with the exception of Hindol, Bhuban, and Kankadahad, showed a decreasing trend in rainfall. No significant trend was detected during the winter.

Table 3.6: Annual and seasonal rainfall trend of Angul district.

Season	Angul	Banarpal	Chhendipada	Talcher	Kaniha	Athmallik	Kishorenagar	Pallahada
Annual								
P Value	0.68	0.00	0.00	0.00	0.00	0.11	0.00	0.00
Sen's slope	-0.88	0.50 (s)	5.36 (s)	16.04(s)	-9.29(s)	-2.03	-9.59(s)	-12.60(s)
Monsoon								
P Value	0.71	0	0.018	0	0.000	0.846	0.000	0.001
Sen's Slope	0.823	9.63 (s)	3.53(s)	11.58(s)	-11.74(s)	-0.84	-12.29(s)	-12.16(s)
Post-monsoon								
P Value	0.48	0.00	0.07	0.00	0.000	0.00	0.000	0.017
Sen's slope	0.41	1.97(s)	0.59	2.91(s)	1.45(s)	1.34(s)	1.97(s)	1.04(s)
Winter								
P Value	0.96	0.02	0.00	0.25	0.68	0.01	0.18	0.01
Sen's slope	0.00	0.00(s)	0.78(s)	0.00	0.00	0.22(s)	0.00	0.00(s)
Summer								
P Value	0.79	0.00	0.55	0.00	0.00	0.30	0.86	0.59
Sen's slope	0.18	2.34(s)	-0.85	2.89(s)	1.34(s)	0.72	0.11	-0.53

Table 3.7: Annual and seasonal rainfall trend of Dhenkanal district

Season	Dhenkanal	Gondia	Odapada	Hindol	Kamakhyanager	Bhuban	Parjang	Kankadahad
Annual								
P Value	0.696	0.06	0	0	0.17	0.0414	0.00	0.02
Sen's slope	1.703	-4.14	-18.26(s)	10.21(s)	-6.14	12.11(s)	-7.93(s)	6.20(s)
Monsoon								
P Value	0.219	0.08	0.000	0	0.04	0.05	0.00	0.08
Sen's slope	-1.764	-3.53	-16.89(s)	8.65(s)	-7.58(s)	4.47	-8.89(s)	3.17
Post-monsoon								
P Value	0.027	0.063	0.39	0	1.01	0	0.10	0
Sen's slope	1.05(s)	-4.137	-0.25	2.55(s)	-0.01	2.73(s)	0.67	1.62(s)
Winter								
P Value	0.776	0.54	0.89	0.56	0.74	0.32	0.81	0.36
Sen's slope	0	0	0	0	0	0	0	0
Summer								
P Value	0	1	0.10	0.69	1	0.07	0.00	0.02
Sen's slope	2.45(s)	-0.01	0.56	0.27	-0.01	3.40	2.68(s)	2.90(s)

4. Conclusion

Rainfall plays a crucial role in the Indian economy. While the monsoon influences the majority of the country, the quantity of rainfall differs significantly across various regions. There is considerable variability in both the regional and temporal distribution of rainfall. The average annual rainfall in the mid-central table land area was 1371mm. The Dhenkanal district recorded the maximum rainfall of 1423mm in this zone. The monsoon season accounted for the largest portion of the total rainfall, contributing between 72% and 86%. The seasonal coefficient of variation was lowest during the monsoon, ranging from 18% to 32%, signifying that rainfall during this period was the most dependable. According to the aforementioned study, it is clear that the rainfall trends in the mid-central table land zone of Odisha present a mixed picture. While most blocks are experiencing a decreasing trend in annual and southwest monsoon rainfall, it is crucial to recognize that this rainfall is vital for crop production; therefore, the blocks facing a decreasing trend should explore alternative strategies such as irrigation. Furthermore, the rise in post-monsoon and winter rainfall across most blocks in this region highlights the significance of cultivating Rabi crops. Leveraging long-term regional weather data to assess the impacts of climate change, such as extreme weather patterns and their effects on the local environment, requires urgent focus for better agricultural planning and management.

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