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Rainfall characterisation and trend analysis of North Central plateau zone of Odisha

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Abstract
Investigation of trends and variability in rainfall patterns is of paramount importance for the effective planning and management of rain fed cropping systems. A detailed analysis was carried out to understand the changes in rainfall patterns and characteristics at a regional scale on agro-climatic zone basis, in North central plateau zone (Keonjhar and Mayurbhanj dist.) of Odisha. This study found that mean annual rainfall of North Central Plateau zone is 1450 mm, with an average of 67 rainy day. CV of annual rainfall of different blocks varies between 20-37%. This zone receives 63% & 67% of mean annual rainfall during SW monsoon in Keonjhar and Mayurbhanj district respectively. The Mann–Kendall (MK) test was used for the analysis of increasing and decreasing (monotonic) trends. It was also observed that annual rainfall in some of the blocks showing increasing trend and others are found to have significant decreasing trends in the magnitude of rainfall during the non-monsoon season. At 75% probability this zone received 1150 mm rainfall, which is good amount of rainfall for crop production. Mean annual maximum temperature of this zone was 31.5 °C and minimum temperature was 20 °C. Monsoon starts effectively from 22nd week (9 June to 15 June) in North central plateau zone and remain active up to 41th week (9th October to 13th October). Rice nursery bed preparation can be started by 22nd SMW and harvesting operation can be completed by 38th-42nd week by selecting medium to long duration varieties. On upland and medium lands, early sowing of pre-rabi crops like cow pea, horse gram, green gram, black gram, Niger, tomato, cabbage, cauliflower, okra, and leafy vegetables to be done to conserve soil moisture.

Keywords: Rainfall trends and variability, Mann–Kendall test, weather cock, spatio-temporal variation

Introduction
Odisha is an agriculture dominant state and rainfall plays a vital role in its economy. Moreover, droughts are not new to Odisha, as they are being experienced in the state almost on a regular basis. Initial field preparation, planning of crop sowing, planting and carrying out all agricultural operations in an area requires the details of distribution of rainfall, onset and withdrawal of rainy season and periods of dry and wet spells. The crops can be saved by analysing the rainfall variability and deciding the probability of dry and wet spells using Markov chain probability model before sowing of the crops (Pandarinath, 1991) [4]. With the recession of monsoon coming to an end in the month of October, the rainfall pattern during the period does not augur well for the state. To find out the reason of the reducing crop yield while increasing irrigation and other cultivation inputs in the region, changing climate, i.e., deficient soil moisture availability due to changed rainfall patterns may provide a better explanation of the situation. Based on ecological land classification, NARP delineated Odisha into 10 major agro-climatic zones under four physiographic divisions. In view of the above, the present study has been undertaken to contribute base line information on the agro-climatic aspects of North central plateau zone (Keonjhar & Mayurbhanj District) with special reference to a few major crops representing different parts of this zone. Probable fluctuations in rainfall and temperature have also been reported.

Materials and Methods
The study has been conducted for North central plateau zone (consist of Keonjhar & Mayurbhanj dist.) of Odisha for rainfall characterisation and probability analysis. The Mayurbhanj district comprises of 26 blocks and the Keonjhar district of 13 blocks. But North Central Plateau zone covers 37 blocks except Anandpur and Ghasipura. The total geographical area of the zone is 15,62,825 ha. The net sown area in the zone is 6,92,827 ha.

The total cultivable land in the zone is 9,25,003 ha and irrigated area is 1,51,509 ha. Daily rainfall data at block level were collected from Special Relief Commissioner (SRC), Government of Odisha over the period of 1989 to 2019. Daily temperature data from 1989-2019 were collected from the software called ''NASAPOWER" and KVK. Annual, seasonal, monthly and weekly rainfall values were computed using daily data series for 31 years period (1989– 2019). In this study, software namely, 'Weather Cock' was used for weather data analysis. Trend was calculated using a software named TREND. It performed the trend analysis which is based on Mann-Kendall test.

Spatial and temporal variability of rainfall

Mean annual, seasonal, monthly and daily rainfall variability was found out by analysing rainfall block wise over a period of 31 years. Block wise daily rainfall data were collected from Special Relief Commissioner (SRC), Odisha and the data were processed by using Weather cock. "Rainy Day.exe" module was used to analyse the rainfall data. Year wise annual rainfall and rainy days along with Standard deviation and coefficient of variation have also been estimated. Trend lines have also been shown in the respective graphs.

Annual rainfall and rainy days

A day with rainfall of amount equal or more than 2.5 mm was considered as a rainy day according to India Meteorological Department for Indian region. Mean annual rainfall and rainy days of each block in this zone were computed over the period of 31 years by the help of "Rainy day.exe" module. Standard deviation (SD) and Co-efficient of variance (CV) were calculated by using statistical equation.

Monthly rainfall and rainy days

Mean monthly rainfall and rainy days for each block were calculated by the same module used in seasonal and annual rainfall analysis. Standard deviation and Co-efficient of variance for every month were calculated by using statistical equations.

Seasonal rainfall and rainy days

As per Odisha condition the whole year was categorised into four major season's namely SW monsoon, post-monsoon, summer and winter. Monsoon season consists of four months, namely, June, July, August and September. Post-monsoon consists of two months, namely, October, November and December, January and February are under winter season. March, April and May are under summer season.SD and CV were also computed for four seasons. Seasonal rainy days and rainfall analysis for each block were also done by the same module which was used for annual rainfall and rainy days analysis.

Trend analysis of annual rainfall

Trend analysis is the practice of collecting information and attempting to find a pattern or trend in the information. It involves analysis of time series data that compares some variable over a significantly long period to detect general pattern and project the future direction of this pattern. Trend of annual rainfall have been evaluated block wise. Annual rainfall data of 31 years (1989- 2019) for each block were computed and put in 'Trend calculator'. The output of trend analysis is obtained in the form of critical values of test statistics at significance levels of $\alpha = 0.01$, $\alpha = 0.05$ and $\alpha = 0.1$. It indicates 99%, 95% and 90% significance respectively. Trend was also observed by plotting graph of annual rainfall against year for each block.

Probability Analysis of Rainfall

Markov chain probability model for dry and wet spell analyses

In this study, weekly rainfall values have been computed from daily data series and were used for estimation of initial and conditional probability analysis based on Markov chain probability model as described by Pandarinath, 1991 [4]. In this method, 20 mm or more rainfall in a week is considered as wet week otherwise dry as the previous researchers (Pandarinath, 1991; Dash and Senapati, 1992) [4, 1] also used 20 mm as the threshold value. Initial, and conditional probability analysis for 52 SMWs were made by using equations from 1-6.

Initial probability

$$P(D) = F(D)/N \quad \text{(Eq. 1)}$$

$$P(W) = F(W)/N \quad \text{(Eq. 2)}$$

Where, P (D) = probability of the week being dry, F (D) = frequency of dry weeks, P (W) = probability of the week being wet, F (W) = frequency of wet weeks, and N = total number of years of data being used.

Conditional probabilities

$$P(DD = F(DD)/F(D) \quad \text{(Eq. 3)}$$

$$P(WW) = F(WW)/F(W) \quad \text{(Eq. 4)}$$

$$P(WD) = 1 – P(DD) \quad \text{(Eq. 5)}$$

$$P(DW) = 1 – P(WW) \quad \text{(Eq. 6)}$$

Where, P(DD) = probability of a week being dry preceded by another dry week, F(DD) = frequency of dry week preceded by another dry week, P(WW) = probability of a week being wet preceded by another wet week, F(WW) = frequency of a wet week preceded by another wet week, P(WD) = probability of a wet week preceded by a dry week, and P(DW) = probability of a dry week preceded by a wet week.

Meteorological drought frequency

Daily rainfall data of past 31 years were used to calculate the percentage of occurrence of drought with the help of module named as "Meteorological Drought".

Results and Discussion

Annual rainfall and rainy days

Average annual rainfall of Keonjhar district 1353 mm. Variability of district annual Rainfall varies 22-37%. The blocks receiving more than the districts average rainfall were Keonjhar, Telkoi, Ghatagaon, Joda and Champua. Average annual rainy days of this district was 63 days. Average annual rainfall of Mayurbhanj district 1547 mm. At block level great spatial heterogeneity has been observed. Highest rainfall occurred in Baripada (1959 mm) and lowest rainfall of 1061 mm occurred in Sarasakana. Maximum number of rainy day (80 days) was recorded in Thakurmunda and minimum number of rainy day (58 days) was in Jamda. Average annual rainy days of this district was 71 days (Fig. 1).

The average annual rainfall of North Central Plateau zone was 1451 mm. Out of 2 district highest rainfall was received in Mayurbhanj district i.e.,1547 mm. Variability of the annual rainfall was 16% to 37%. Average annual rainy days of this

zone 66 days.

Pasupalak (2015) [5], reported that the variability of annual rainfall in Odisha was 21%. Eight districts had high variability (>23%), while 10 districts had low variability (<20%). Variability was maximum (25%) in Sonepur district and minimum (16%) in Sundargarh district. Present results confirm the results of Pasupalak (2015) [5] for the Bhadrak district.

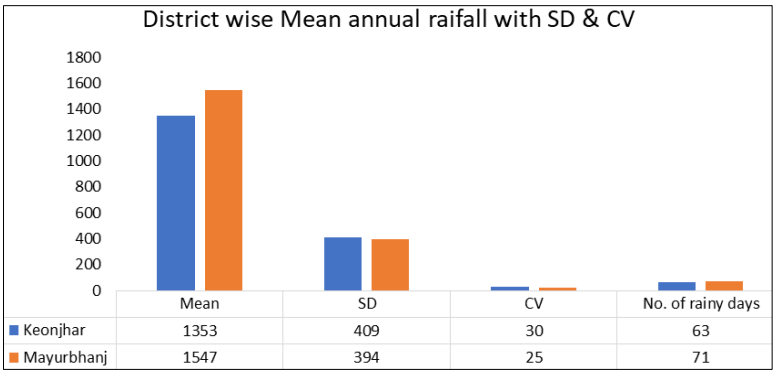


Fig 1: District wise Mean annual raifall with SD & CV

Monthly rainfall

Monthly average rainfall of this zone (Both for Keonjhar & Mayurbhanj dist.) is presented in (Fig. 2 & 3). July month receive the highest rainfall in both the district (256 mm & 266 mm) followed by august month (237mm and 245 mm respectively for Keonjhar & Mayurbhanj). The lowest rainfall received in January (32 mm) in Keonjhar and in December (39 mm) in Mayurbhanj district. The variability was minimum (16%) in the month of July and while maximum (61%) variability was seen in December.

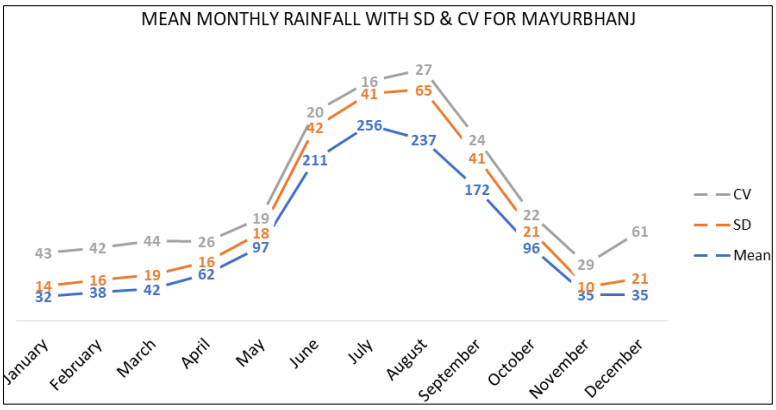


Fig 2: Mean monthly rainfall with SD & CV for Mayurbhanj

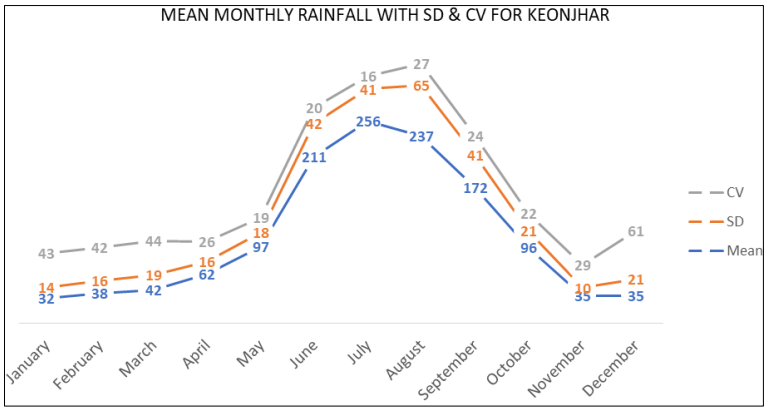


Fig 3: Mean monthly rainfall with SD & CV for Keonjhar

Seasonal rainfall and rainy days

Analysis of seasonal rainfall of this zone was carried out using rainfall data of 31 years (1989-2019) and the results are presented in (Fig 4). Seasonal analysis of rainfall was done for four seasons: SW monsoon (June to September), post-monsoon (October to November), winter (December to February) and summer (March to May).

South West Monsoon

In Keonjhar district South West monsoon contribute about 64% of the normal annual rainfall (Fig 4). The district average SW monsoon rainfall is 832mm±344mm. Variability of

rainfall during SW monsoon was 41% in the district. Average number of rainy days during SW monsoon in the district was 39 days (Fig 4).
In Mayurbhanj district South West monsoon contribute about 65% of the normal annual rainfall. The district average SW monsoon rainfall is 944mm±297 mm. Variability of rainfall during SW monsoon was 32% in the district. Average number of rainy days during SW monsoon in the district was 42 days (Fig 4).

Post-Monsoon
Post monsoon rainfall of Keonjhar district was 177mm which was 13% of total annual rainfall. The variability of post-monsoon rainfall in the district (64%). Number of rainy days in the district is 9.
Post monsoon rainfall of Mayurbhanj district was 191mm which was 13% of total annual rainfall. The variability of post-monsoon rainfall in the district was (66%). Number of rainy days in the district is 9.

Winter
The winter rainfall contributes lowest amount of rainfall for both the district (7% & 6%) respectively towards the normal annual rainfall of the zone. Mayurbhanj district received maximum (98 mm) winter rainfall followed by Keonjhar district (82 mm). Winter rainfall was highly variable in Keonjhar district (77%). Average rainy days of both the district in winter was 4 & 5 respectively (fig 4).

Summer
The average summer rainfall in this zone was 242 mm i.e. for Keonjhar district (222 mm) & for Mayurbhanj dist. (262 mm) which is 16% & 17% of total annual rainfall of both the district. Kaptipada block of Mayurbhanj district received highest summer rainfall of about 386 mm and lowest in Tiringi block of Mayurbhanj district. 128 mm (Fig 4). Variability of summer rainfall is 54% & 46% for Keonjhar and Mayurbhanj respectively, which is highest in Banspal block of Keonjhar district (83%).
The summer monsoon rainfall over northeast India showed characteristic spatial and temporal variability due to the interaction of basic monsoon flow with orography and the synoptic scale systems developing over Indian region (Mohapatra *et al*. 2011) [2].

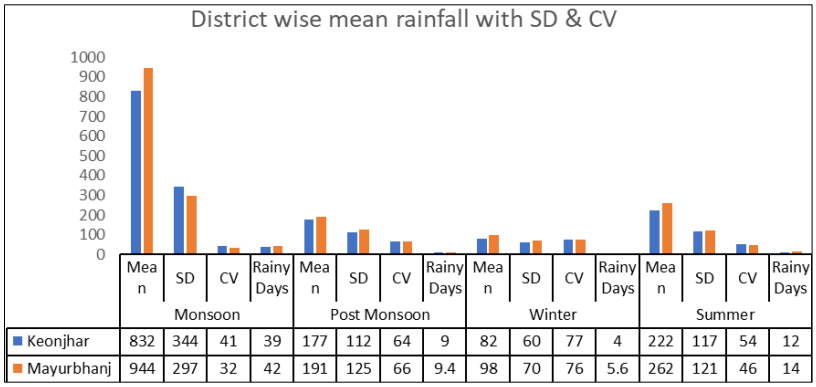


Fig 4: District wise mean rainfall with SD & CV

Annual rainfall trend
Block level rainfall data of 30 years (1990– 2019) of Keonjhar and Mayurbhanj district were subjected to Mann-Kendall test for detecting trend in annual rainfall at three different significance level i.e., 90%, 95% and 99%. The results of Mann-Kendall test are presented in (Table 1). Plot of annual rainfall (mm) with time (year) has been presented graphically in Figure 5 & 6. For further quantitative analysis and corroborative study, we have used TREND software and the results are presented in (Table 1).
In Keonjhar, out of 11 blocks Saharpada and Hathidi showed an increasing trend at 90% & 95% significance level. Keonjhar block showed a decreasing trend at 99% significance level. No significance trend was observed in remaining 8 blocks (Table 1).

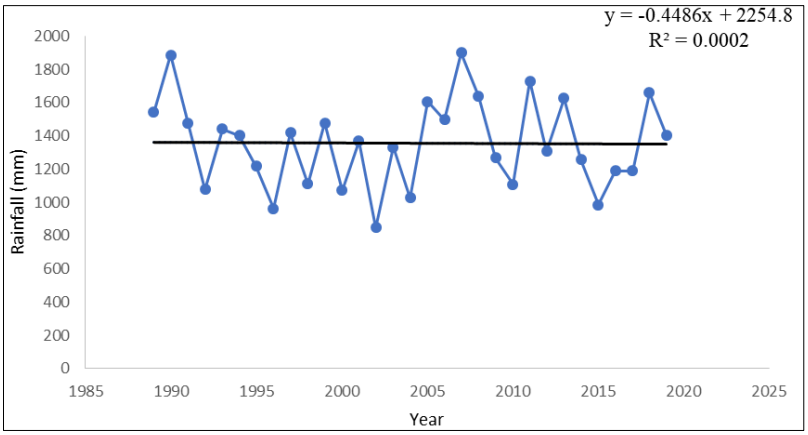
Table 1: Annual rainfall trend of Keonjhar using Mann Kandell-Test

Block	Test stat	Critical Values			Result
		A=0.1	A=0.05	A=0.01	
Keonjhar	-3.467	1.645	1.96	2.576	S (0.01)
Banspal	0.204	1.645	1.96	2.576	NS
Telkoi	-0.578	1.645	1.96	2.576	NS
Patna	1.36	1.645	1.96	2.576	NS
Saharpada	1.649	1.645	1.96	2.576	S (0.1)
Ghatgaon	0.204	1.645	1.96	2.576	NS
Harichandanpur	-1.02	1.645	1.96	2.576	NS
Hatadihi	2.43	1.645	1.96	2.576	S (0.05)
Champua	-0.442	1.645	1.96	2.576	NS
Joda	0.425	1.645	1.96	2.576	NS
Jhumpura	1.462	1.645	1.96	2.576	NS

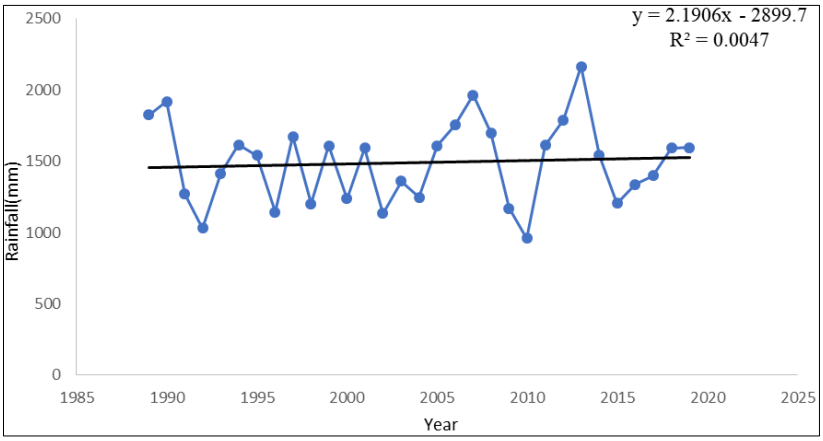
In Mayurbhanj, out of 26 blocks Betanati, Jamda showed an increasing trend at 99% significance level and Bahalda at 90% significant level. Badasahi, Karanjia block showed a decreasing trend at 99% significance level & Besoi at 95% significance level. No significance trend was observed in remaining blocks (Table 2).

Table 2: Annual rainfall trend of Mayurbhanj using Mann Kandell-Test

Block	Test stat	Critical Values			Result
		A=0.1	A=0.05	A=0.01	
Samakhunta	-0.714	1.645	1.96	2.576	NS
Badasahi	-1.666	1.645	1.96	2.576	S (0.1)
Betanati	2.685	1.645	1.96	2.576	S (0.01)
Morda	0.85	1.645	1.96	2.576	NS
Rasgovindapur	-1.632	1.645	1.96	2.576	NS
Kuliana	-0.34	1.645	1.96	2.576	NS
Sarasakana	0.629	1.645	1.96	2.576	NS
Suliapada	0.357	1.645	1.96	2.576	NS
Bangriposi	0.578	1.645	1.96	2.576	NS
Baripada	1.564	1.645	1.96	2.576	NS
Khunta	0.272	1.645	1.96	2.576	NS
Gopabandhunagar	0.374	1.645	1.96	2.576	NS
Udala	-0.34	1.645	1.96	2.576	NS
Kaptipada	0.816	1.645	1.96	2.576	NS
Besoi	-2.346	1.645	1.96	2.576	S (0.05)
Bijatala	0.612	1.645	1.96	2.576	NS
Rairangapur	1.088	1.645	1.96	2.576	NS
Kusumi	1.394	1.645	1.96	2.576	NS
Jamda	3.297	1.645	1.96	2.576	S (0.01)
Bahalda	1.819	1.645	1.96	2.576	S (0.1)
Tiring	-0.646	1.645	1.96	2.576	NS
Joshipur	-0.034	1.645	1.96	2.576	NS
Karanjia	-1.666	1.645	1.96	2.576	S (0.1)
Thakurmunda	-0.238	1.645	1.96	2.576	NS
Surukuli	-0.408	1.645	1.96	2.576	NS
Raruana	-1.088	1.645	1.96	2.576	NS



Keonjhar



Mayurbhanj

Fig 5: District wise graphical representation of rainfall trend analysis

Initial and Conditional Probability (Markov Chain Model)

The initial rainfall probability {P (W)} of getting 20 mm rainfall per week was >30% during 22 SMW in this zone (Keonjhar and Mayurbhanj district) and hence, field preparation should be done during this period. The pre-monsoon rain can be utilized for summer ploughing, sowing dhaincha and seed bed preparations. The initial as well as conditional probability of wet week followed by wet week {P(W/W)} of getting 20 mm rainfall was more than 50% in 22 SMW at Keonjhar district and in Mayurbhanj it is 23 SMW. Therefore, this week is more suitable for sowing of direct seeded low land rice. Nursery preparation of rice can also be planned. Further delay in sowing may cause very low productivity and even crop failure. Nurseries for transplanted paddy can be sown either in 23 and 24 SMW (4th – 17th June) with the pre-monsoon showers which seems to be sufficient to bear the normal soil moisture range and afford good germination. The direct sown paddy and paddy nurseries will be ready for further cultural operation and transplantation with the onset of monsoon (24 to 25 SMW).

Since the initial probability of wet spell P(W) and conditional probability of dry followed by wet week P(W/D) and wet followed by wet week P(W/W) is high between SMW 24 to 39, hence crop can be planned during this period. North Central Plateau zone (both Keonjhar and Mayurbhanj district) comes under moist sub-humid climate where humid period is more than 12 weeks duration and the rainfall is twice that of PET. Hence, paddy-based cropping system is suitable on lowlands as both the district receives good monsoon rainfall which is sufficient for the paddy during kharif season where other crops could not withstand water stagnation. Medium duration rice varieties can easily be grown with little fear of drought at reproductive stage. Moreover, the residual soil moisture after the harvest of rice can be effectively utilised for raising another short duration crop like lentil, mustard, greengram and biri in winter.

Meteorological drought frequency

Meteorological drought analysis of North Central Plateau zone (based on 31 years data) showed several years under different intensity of drought and their percentage occurrence for 37 blocks of both (Keonjhar& Mayurbhanj) district (Table 3 & 4). Occurrence of moderate drought was found to be a common feature in both the district.

In Keonjhar district Hathidi, Saharpada and Keonjhar block (Table 3) was highly affected by moderate drought, which occurred in 8 years (26%) and once with 3 consecutive years. Among the blocks affected by a severe drought once in the year, though Ghatagaon received highest annual rainfall of 1711 mm. Probabilities of occurrence of moderate droughts at different blocks of Keonjhar district was ranging from 3 to 26%. The probability of occurrence of no droughts was 70 to 90%.

Table 3: Frequency of Meteorological drought occurrence (Keonjhar)

Block	No drought		Moderate drought		Severe drought	
	No. Of years	% Of years	No. Of years	% Of years	No. Of years	% Of years
Keonjhar	23	74	8	26	0	0
Banspal	27	73	3	8	1	3
Telkoi	27	77	7	23	0	0
Patna	25	81	5	16	1	3
Saharpada	23	71	8	26	0	0
Ghatgaon	26	70	2	5	3	9
Harichandanpur	24	77	6	19	1	3
Hatadihi	23	74	8	26	0	0
Champua	29	78	1	3	1	3
Joda	28	90	3	10	0	0
Jhumpura	28	90	2	6	1	3

In Mayurbhanj district Suliapada, Badasahi and Jamda block (Table 4) was highly affected by moderate drought, which occurred in 7 years (23%). Bijatala block was worst affected by severe drought, which occurred in 3 years (1992 & 1998). The blocks affected by a severe drought once in the year. Probabilities of occurrence of moderate droughts at different blocks of Mayurbhanj district was ranging from 3 to 26%. The probability of occurrence of no droughts was 70 to 90% (Table 4)

Table 4: Frequency of Meteorological drought occurrence (Mayurbhanj)

Block	No drought		Moderate drought		Severe drought	
	No. Of years	% Of years	No. Of years	% Of years	No. Of years	% Of years
Samakhunta	28	90	3	10	0	0
Badasahi	24	77	7	23	0	0
Betanati	25	81	6	19	0	0
Morda	23	74	8	26	0	0
Rasgovindapur	27	87	3	10	1	3
Kuliana	27	87	4	13	0	0
Sarasakana	25	81	6	19	0	0
Suliapada	24	77	7	23	0	0
Bangriposi	28	90	3	10	0	0
Baripada	28	90	3	10	0	0
Khunta	30	81	0	0	1	3
Gopabandhunagar	30	81	0	0	1	3
Udala	30	97	1	3	0	0

Kaptipada	28	90	3	10	0	0
Besoi	24	77	6	19	1	3
Bijatala	25	81	4	13	2	6
Rairangapur	26	84	5	16	0	0
Kusumi	26	84	5	16	0	0
Jamda	24	77	7	23	0	0
Bahalda	26	84	4	13	1	3
Tiring	27	87	3	10	1	3
Joshipur	28	90	3	10	0	0
Karanjia	28	90	2	6	1	3
Thakurmunda	27	87	3	10	1	3
Sukuruli	28	90	3	10	0	0
Raruana	27	87	4	13	0	0

Conclusion

Existing spatial and temporal variability of rainfall in north central plateau zone reveals various trends and rainfall patterns. Graphical presentation of the trend of annual rainfall together with results of Mann-Kendall test shows increasing, constant and decreasing trend in different blocks over years. In case of seasonal rainfall this zone received almost 61-62% of mean annual rainfall during SW monsoon. Variability of rainfall during SW monsoon was 26-50% in this zone The CV of seasonal rainfall except South west monsoon is higher than the threshold (50% for seasonal rainfall) except some blocks like Joda, Badashi and Raurana. So, all blocks are receiving good quantum of rainfall upon which farmers can rely for their crop water demand during monsoon season. It can also be inferred that rainfall is not much dependable during pre-monsoon and post monsoon period since the rainfall variability is greater than 50%. So, we need alternative irrigation and adjustment of date of sowing besides taking precautionary measures to save matured crops and harvested produce. Land preparation and sowing of pulses and oilseeds should be completed immediately after the harvest of paddy on residual moisture under rain fed condition. On upland and medium lands, early sowing of pre-rabi crops like cow pea, horse gram, green gram, black gram, Niger, tomato, cabbage, cauliflower, okra, and leafy vegetables to be done to conserve soil moisture.

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