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Detrend yield analysis of small millets and annual and seasonal precipitation concentration index for 27 districts of Chhattisgarh state

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Abstract
In the detrended yield during crop growing period rainfall (June –October) and detrend yield. It was found 9 districts of Chhattisgarh (Bemetara, Dantewada, Durg, Gariyaband, Jahangir Champa, Kondagaon, Korba, Koriya and Rajnandgaon) showed significant level and their out of 9 districts we were found 4 districts (Dantewada, Janjgir Champa, Korba and Koriya) of Chhattisgarh showed highly significant increasing trend at 1% level. Remaining 5 districts (Bemetara, Durg, Gariyaband, Kondagaon and Rajnandgaon) also increasing trend but significant at 5% level. Rest of 18 districts was showed increasing trend but non-significant during the study period (2011-2020). The ranges of annual PCI values were found that 20.1 to 29.3%. The maximum value was 29.3% found in Surajpur district, the minimum annual PCI was calculated that 20.1% in Jagdalpur district. In the result shows that of entire state of annual PCI value was 25.8%. It depicts (rainfall distribution) and in addition, the PCI distribution is not uniform over the entire study areas in annual basis. All districts was found that >20% of PCI values that considered in strong category irregularity of precipitation distribution. In seasonal PCI values of range found from 8.4-11.2%, the maximum SPCI value found that 11.2% in Surajpur district. While 8.4% in Bemetara district of minimum PCI value The average SPCI value in state of Chhattisgarh was found 10.3% this value depicted rainfall of Chhattisgarh according to SPCI categorization it comes under moderate precipitation districts. The maximum% contribution based on seasonal rainfall PCI value 47.6% in Jagdalpur, minimum% contribution 31.0% in Bemetara. Average percentage contribution SPCI of rainfall was 39.8% of the Chhattisgarh state.

Keywords: Detrended yield, precipitation concentration, rainfall distribution

1. Introduction
The important characteristic of the Indian rainfall is that it is mostly monsoonal. Having varied topography and large geographic extent in the tropics, the Indian climate varies substantially due to unstable monsoon and other weather conditions. About 80% of the annual rainfall received during the monsoon months of June to September. Chhattisgarh state 87% of the annual rainfall received during the monsoon months of June to September. In Chhattisgarh state maximum precipitation comes in Baster plateau and Northern hill zone and maximum rainfall received Bijapur district in Baster plateau and minimum rainfall received Kabirdham district in Chhattisgarh plain zone. Valli *et al.* (2013) [4] investigated that the changes in the temporal distribution of rainfall using a 30-year record of monthly precipitation to detect monthly, seasonal, and annual distribution, variations, and trends in eleven Andhra Pradesh districts. For the period 1981-2010, the Precipitation Concentration Index was evaluated on an annual and seasonal scale to determine the pattern of rainfall in the research area, which revealed an uneven distribution of rainfall with values ranging from 16 to 35.
A detrend involves removing the effects of technology from a data set to show only the differences in values from the trend it allows cyclical and other patterns to be identified Detrending shows a different aspect of time series data by removing deterministic and stochastic trends.

2. Review of literature
Caloiero *et al.* (2019) [1] repeated that the long term rainfall data of 84 stations collected from 158 rain gauges station of Sardinia region was used to find out the precipitation concentration index. The PCI has been assessed and distributed geographically. The results of the study show that the PCI values in the two sides of the region are different, indicating that orography has a significant impact.

The eastern half of the region had PCI values that corresponded to a climate with significant monthly precipitation fluctuation, indicating that rainfall is reduced during the winter months. The precipitation concentration index was used to analyze the monthly rainfall distribution throughout the year (PCI). A negative trend occurred, with a tendency toward a more uniform rainfall distribution across Sardinia throughout the year.

Sanguesa *et al.* (2018) [3] repeated that the Spatial and Temporal Analysis of Rainfall Concentration Using the precipitation concentration index in Chile from the period of 1970 to 2016. There was 30 percentage decreases in precipitation concentration index in humid sub-humid zone stations. It was also discovered that PCI values were 33.6 percent in the arid and semiarid zones, but were only 16.4 percent in the humid and sub-humid zones. This explains the wide variation in this indicator's values from one zone to the next, with values ranging from 20.7 percent to 58.6 percent in the dry and semi-arid zone and 13.3 percent to 19.6 percent in the humid and sub-humid zone. This means that, on an annual basis, PCI in both research locations found no indication of increases or declines in the concentration of yearly precipitation over time.

Rasel *et al.* (2016) [2] examined that the annual and seasonal precipitation concentration index of north- western area in Bangladesh over the period of 2000-2011. The estimation were based on two seasons dry seasons (November to April) and wet season (May to October) (May to October). During the rainy season, PCI values range from 25.0 to 30.7, indicating a highly erratic rainfall distribution. The annual PCI value revealed an erratic rainfall distribution, with values ranging from 17.6 to 18.8. The PCI value has climbed in Syedpur, Rangpur, Dinajpur, and Bogra, whereas it has decreased in Rajshahi and Ishwardi.

Zhang *et al.* (2009) [5] reported that variation in trend of annual PCI values was decreased significantly at the rate of -234/10 year (a=0.1) in china over the last 57 years. Out of 597 stations 434 station which covers 72.7% area showed decreasing trends and Precipitation Concentration Index values was also in decreasing trend. In China, precipitation concentration was strongly irregular in the western and northern parts of the northwest, as well as in the northern region of the Tibetan plateau, while it was irregular in the southwest and north, and moderately irregular in some parts of the Yangtze River's middle and lower regions, as well as in southern China. From south-eastern to north-western China, the uniformity of the annual precipitation pattern declined dramatically in spring, autumn, and winter, and was highest in winter. Summer precipitation dispersion and pattern, on the other hand, were more consistent than the other seasons over the study period.

3. Material and Methods

The data used for this study was obtained from secondary sources. Annual and seasonal rainfall figure for the period of 1991-2020, has been collected from department of Agrometeorology, IGKV, Raipur (C.G).

Per standard procedure, the Precipitation Concentration Index of annual and seasonal rainfall was calculated. The Precipitation Concentration Index (PCI) was working as statistical measures of rainfall variability.

Oliver (1980), proposed the Precipitation Concentration Index as an indicator of rainfall concentration and rainfall erosivity. Michiels *et al* (1992) evaluated the PCI and calculated its values on annual and seasonal scale through the following formulae;

$$APCI = \left[\frac{\sum Pi^2}{(\sum Pi)^2}\right] \times 100$$

$$SPCI = \frac{\sum_{i=1}^{4} pi^2}{(\sum_{i=1}^{4} Pi)^2} \times 33.3$$

Where

Pi = rainfall amount of the ith month

Σ = summation over the number of months being assessed.

PCI Value (%)	Interpretation
<10	Uniform precipitation distribution
11 to 16	Moderate precipitation distribution
16 to 20	Irregular distribution
>20	Strong irregularity of precipitation distribution

Detrend yield analysis (Yd), also known as time series analysis. De-trending yield data was used to remove the impact of technology over the last 30 years (1971-2010) in order to analyze the impact of rainfall change. The yield data was de-trended by deleting the value of 'b' from the second year of the time series as follows: given below will be calculated with of given formula.

$$Yd = Yn - b(n-1)$$

Where

Yd = detrended yield,

Yn = number of the year,

b = slope

4. Results and Discussion

4.1 Annual and seasonal average value for precipitation concentration index (PCI) in different in different districts of Chhattisgarh. For the period of (1991-2020)

4.2. Annual average values for PCI (Precipitation concentration index) in different district of Chhattisgarh

Precipitation concentration index as an indicator of rainfall concentration and rainfall erosivity. The result of annual rainfall average PCI (precipitation concentration index) values is show in table 1 which indicated that the substantial differences in all 27 districts of Chhattisgarh state regarding distribution of precipitation throughout the (1991-2020). The ranges of annual PCI values found that 20.1 to 29.3%. The maximum value was 29.3% found in Surajpur district followed by Balrampur district 29% and 27.6% in Korba district vice versa the minimum annual PCI was calculated that 20.1% in Jagdalpur district followed by 23.5% in Bilaspur and 23.7% in Sukma district. In the result shows that of entire state of annual PCI value was 25.8%. It depicts (rainfall distribution) and in addition, the PCI distribution is not uniform over the entire study areas in annual basis. All districts was found that >20% of PCI values that considered in strong category irregularity of precipitation distribution. The result was come under this category because annual rainfall obtained by 12 months (January to December), all months have been not received equal rainfall therefore the annual PCI value was more than 20% that was showing strong irregularity of PCI and irregularity of rainfall concentration. The PCI (precipitation concentration index) is a powerful indicator for temporal precipitation distribution and it is also very useful for assessment of seasonal precipitation change.

Table 1: Annual precipitation concentration index (PCI) for different districts of Chhattisgarh.

S. No.	Districts	Annual RF (mm)	APCI (%)
1	Balod	1120	27.2
2	Balodabazar	1071	25.7
3	Balrampur	1143	29
4	Bemetara	1310	27
5	Bijapur	1684	26.8
6	Bilaspur	1190	23.5
7	Dantewada	1400	26.6
8	Dhamtri	1176	27.2
9	Durg	1052	27.1
10	Gariyaband	1148	27.4
11	Jagdalpur	1452	20.1
12	Janjgir C.	1149	27.3
13	Jashpur	1331	24
14	Kabirdham	1000	23.9
15	Kanker	1151	26.9
16	Kondagaon	1249	24.4
17	Korba	1324	27.6
18	Koriya	1233	26.7
19	Mahasamund	1191	25.9
20	Mungeli	1031	25.2
21	Narayanpur	1403	24.9
22	Raigarh	1157	24.5
23	Raipur	1180	25.5
24	Rajnandgaon	1140	25.3
25	Sukma	1573	23.7
26	Surajpur	1350	29.3
27	Surguja	1303	24.6

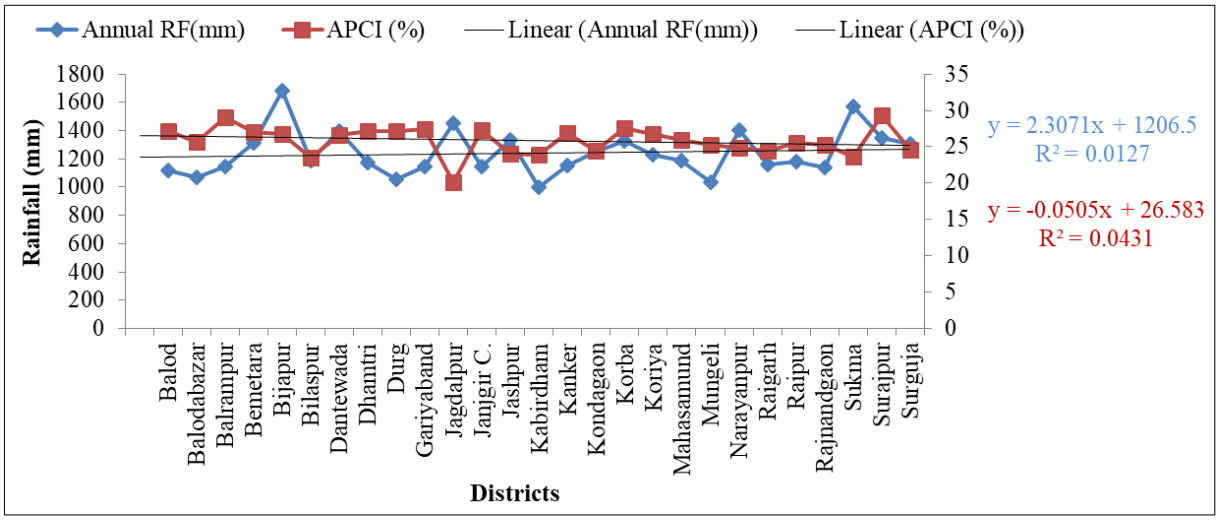


Fig 1: linear trend of Annual precipitation concentration index for Chhattisgarh (1991-20)

4.3 Seasonal SPCI (South West Monsoon Precipitation Concentration Index) in different districts of Chhattisgarh

SPCI (Seasonal precipitation concentration index) values in different districts of Chhattisgarh calculated likewise annual precipitation concentration index. These values of range found from 8.4-11.2%, the maximum PCI value found that 11.2% in Surajpur district followed by 11.1% in Surguja and 11.0% in Janjgir Champa. While 8.4% in Bemetara district of minimum PCI value followed by 9.6% in Jagdalpur and 9.7% in Sukma district. The average SPCI value in state of Chhattisgarh was found 10.3% this value depicted rainfall of Chhattisgarh according to SPCI categorization it comes under moderate precipitation districts. The maximum% contribution based on seasonal rainfall PCI value 47.6% in Jagdalpur district and followed by 45.2% in Surguja district and 43.9% in Bilaspur district. likewise minimum% contribution 31.0% in Bemetara followed by 37.1 and 37.5% in Gariyaband and Balrampur districts. Average percentage contribution SPCI of rainfall was 39.8% of the Chhattisgarh state. In SPCI according to SPCI criteria (seasonal precipitation concentration index) values is <10% comes under uniform precipitation distribution. Out of 27 districts six districts of Chhattisgarh Bemetara, Jagdalpur, Jashpur, Mahasamund, Raigarh and Sukma are come under uniform precipitation distribution interpretation. This category all six uniform rainfall distributed districts was found the minimum value in <10.0%. The minimum SPCI value was found that 8.4% in Bemetara followed by Jagdalpur and Sukma districts 9.6 and 9.7% respectively. Remaining 21 districts were come under category for ranges of precipitation concentration index

values 11 to 16% that means 27 districts were comes under moderate southwest monsoon precipitation distribution categories. As specified by De Luis *et al*. (2000), the lowest theoretical value of PCI is 8.85, indicating a uniform monthly precipitation distribution. According to Oliver's (1980) the SPCI values in autumn are between 9.90 and 21.38% which falls in the range of irregular concentration precipitation. These results indicated that the strong regularity of annual precipitation patterns significantly decrease in monsoon season in Chhattisgarh.

Table 2: Seasonal precipitation concentration index (SPCI) for different districts of Chhattisgarh

S. No.	Districts	SWM RF (mm)	SPCI (%)
1	Balod	1001	10.8
2	Balodabazar	949	10.1
3	Balrampur	1061	10.9
4	Bemetara	783	8.4
5	Bijapur	1512	10.9
6	Bilaspur	1022	10.3
7	Dantewada	1272	10.5
8	Dhamtri	1038	10.6
9	Durg	961	10.4
10	Gariyaband	1079	10.2
11	Jagdalpur	1176	9.6
12	Janjgir C.	1028	11
13	Jashpur	1181	9.8
14	Kabirdham	870	10.1
15	Kanker	1049	10.4
16	Kondagaon	1092	10.2
17	Korba	1208	10.6
18	Koriya	636	10.7
19	Mahasamund	1097	10
20	Mungeli	922	10.1
21	Narayanpur	1271	10.1
22	Raigarh	1046	9.8
23	Raipur	1070	10.1
24	Rajnandgaon	1015	10.2
25	Sukma	1383	9.7
26	Surajpur	1238	11.2
27	Surguja	1119	11.1

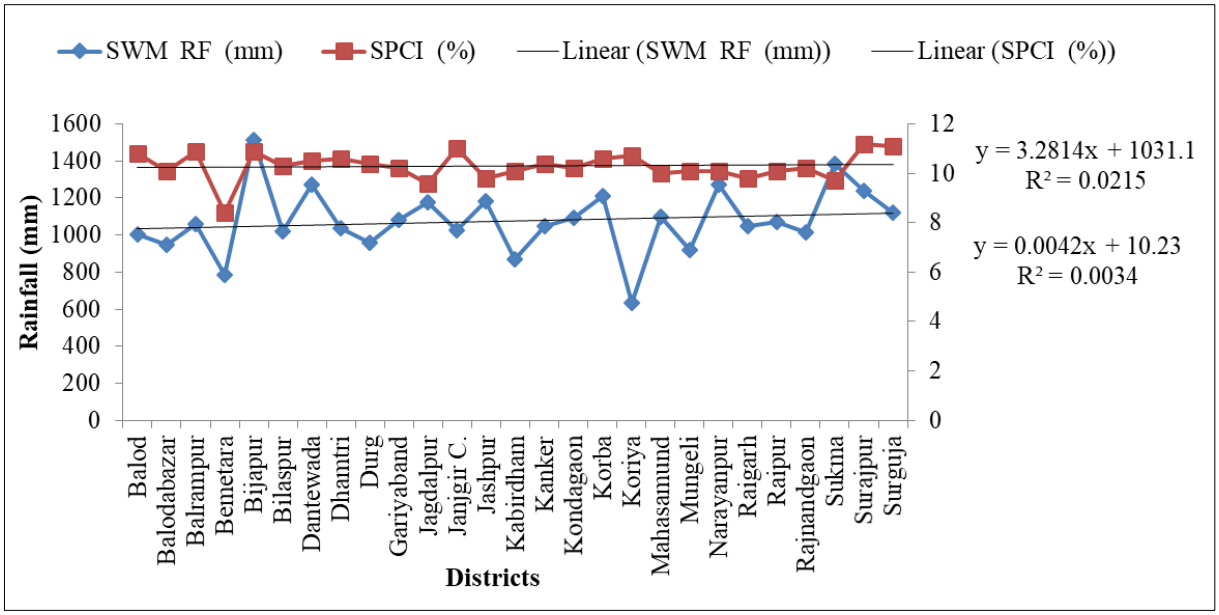


Fig 2: Linear trend of south west monsoon precipitation concentration index (PCI) for Chhattisgarh state (1991-2020)

4.4 Detrend yield analysis of Small millets crop for 27 districts of Chhattisgarh state

A detrend involves removing the effects of technology from a data set to show only the differences in values from the trend it allows cyclical and other patterns to be identified Detrending shows a different aspect of time series data by removing deterministic and stochastic trends. This result interpreted that the technology for crop cultivation is important for small millet's technology in the result of agronomical, approach like weeding, irrigation, fertilization application and crop management and production approaches like as insect pest management are important for all crops but this analysis the result was found more significant in remove technology condition compare to normal with technology

condition. It was observed from the Table 3 First calculated of Small millets growing period rainfall (June –October) and actual yield and it was found only 1 district (Jahangir Champa) showed significantly increasing trend at 5% level. Rest of 26 districts was showed also increasing trend but non-significant level during the study period.

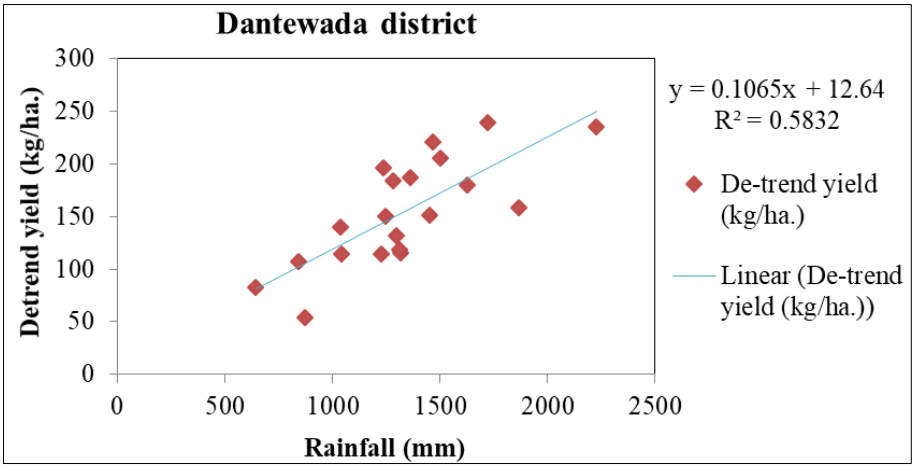
In the detrended yield during crop growing period rainfall (June –October) and detrend yield. It was found 9 districts of Chhattisgarh (Bemetara, Dantewada, Durg, Gariyaband, Jahangir Champa, Kondagaon, Korba, Koriya and Rajnandgaon) showed significant level and their out of 9 districts we were found 4 districts (Dantewada, Janjgir Champa, Korba and Koriya) of Chhattisgarh showed highly significant increasing trend at 1% level. Remaining 5 districts (Bemetara, Durg, Gariyaband, Kondagaon and Rajnandgaon) also increasing trend but significant at 5% level. Rest of 18 districts was showed increasing trend but non-significant during the study period (2011-2020).

From the above study on detrend yield it is understood that the detrend yield during growing period (June to October) in Chhattisgarh state, when compared to actual yield while the significant districts of detrend yield is high than actual yield.

Table 3: Calculated of Small millets growing period rainfall (June –October) and actual yield and it was found only 1 district (Jahangir Champa) showed significantly increasing trend at 5% level

S. No.	Districts	J-O rainfall (mm)	Actual yield (Kg/ha.)	R^2	De-trend Yield (kg/ha.)	R^2
1	Balod	1277	227	0.0521	161	0.0774
2	Balodabazar	903	190.7	0.1611	131	0.3206
3	Balrampur	1173	297	0.3001	230	0.1047
4	Bemetara	797	264	0.1019	134.8	0.5284*
5	Bijapur	1908	222.89	0.4033	145.09	0.4319
6	Bilaspur	1041	324.1	0.0034	179.7	0.0854
7	Dantewada	1329	183.18	0.1124	154	0.5832**
8	Dhamtri	1001	180	0.0004	140	0.234
9	Durg	1015	186.87	0.0005	141.4	0.4561*
10	Gariyaband	1088	230.64	0.2666	161.2	0.4894*
11	Jagdalpur	1348	221.85	0.133	179.7	0.0148
12	Janjgir C.	1070	245.7	0.4557*	206.98	0.6512**
13	Jashpur	1087	287.29	0.0341	217.7	0.3886
14	Kabirdham	821	246.4	0.0795	188.1	0.3903
15	Kanker	1133	279.1	0.1566	124.6	0.1077
16	Kondagaon	1238	229.00	0.4323	171.70	0.4466*
17	Korba	1196	291.96	0.1111	181	0.5915**
18	Koriya	1141	229.9	0.0523	135.58	0.5401**
19	Mahasamund	1123	225.16	0.0542	103.95	0.182
20	Mungeli	929	331.89	0.0255	327.08	0.0331
21	Narayanpur	1408	196.80	0.1637	84.45	0.075
22	Raigarh	1118	275.09	0.1286	149.79	0.1368
23	Raipur	1144	254.5	0.0294	57.6	0.0006
24	Rajnandgaon	1083	254.56	0.0001	171.53	0.465*
25	Sukma	1829	248.9	0.0003	150.9	0.146
26	Surajpur	1533	272.17	0.0191	234.98	0.0019
27	Surguja	1122	261.6	0.001	238.52	0.0007

Level of significance 1%**
Level of significance 5% *



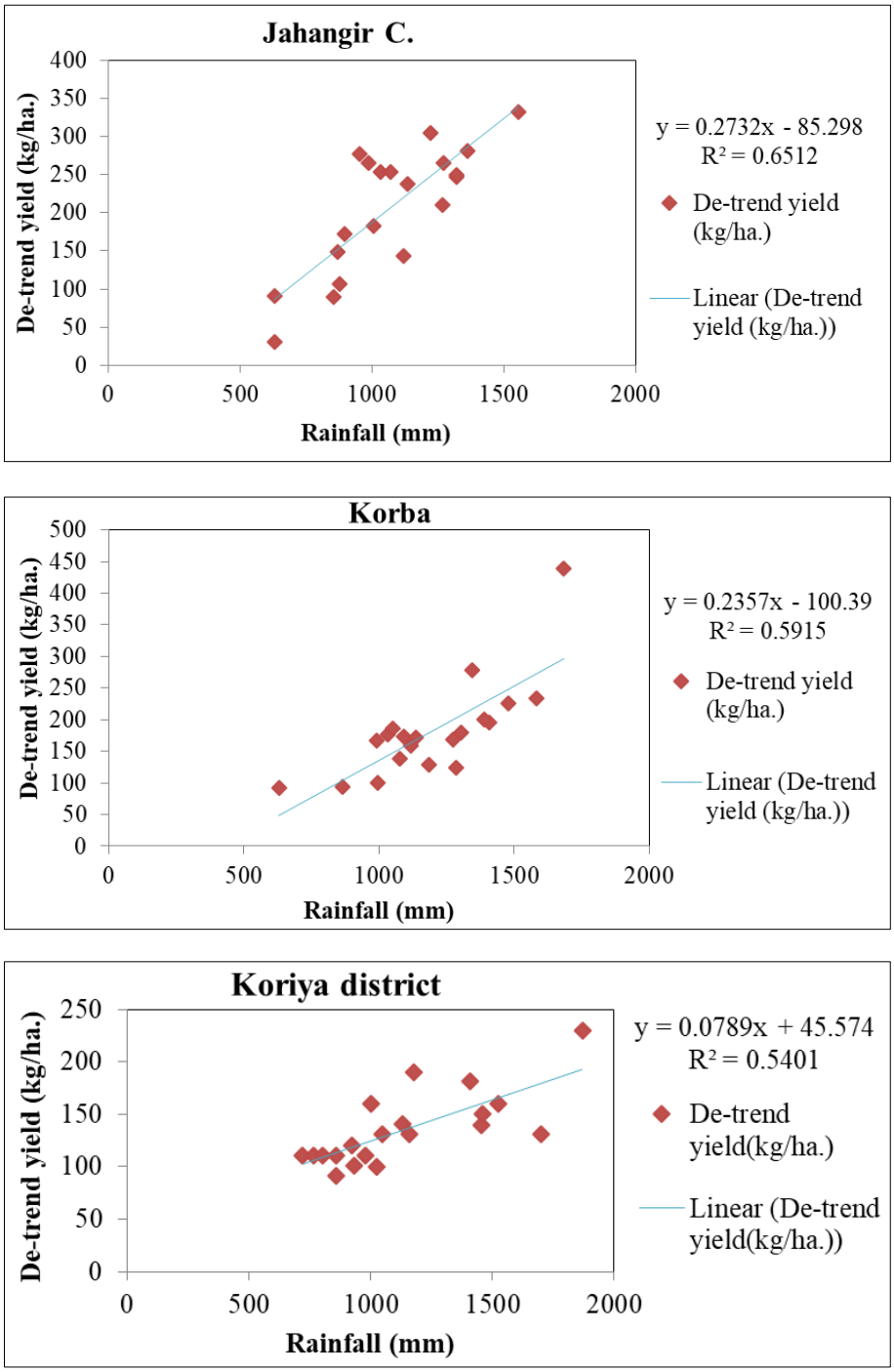


Fig 3: Trends of detrended yield for 4 significant districts across the Chhattisgarh state (2011 – 2020)

5. Conclusion

The ranges of annual PCI values found that 20.1 to 29.3%. The maximum value was 29.3% found in Surajpur district, the minimum annual PCI was calculated that 20.1% in Jagdalpur district. In the result shows that of entire state of annual PCI value was 25.8% this value depicted rainfall of Chhattisgarh according to APCI categorization it comes under strong precipitation districts. In seasonal PCI values of range found from 8.4-11.2%, the maximum SPCI value found that 11.2% in Surajpur district, While 8.4% in Bemetara district of minimum PCI value. The average SPCI value in state of Chhattisgarh was found 10.3% this value depicted rainfall of Chhattisgarh according to SPCI categorization it comes under moderate precipitation districts. In De-trended yield has been worked out for 27 districts of Chhattisgarh. We were found only 4 districts (Dantewada, Janjgir Champa, Korba and Koriya) of Chhattisgarh showed highly significant and increasing trend at 1% level of significant and the rate of change is observed 0.106 kg/ha./year, 0.273 kg/ha./year, 0.235 kg/ha./year and 0.078 kg/ha./year for the period of 2009-2019.

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