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K Singh
Department of Agricultural Meteorology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

R Paikaray
Department of Agricultural Meteorology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

SBB Behera
Department of Agricultural Meteorology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

A Baliarsingh
Department of Agricultural Meteorology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

A Nanda
Department of Agricultural Meteorology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

AKB Mohapatra
Department of Agricultural Meteorology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Corresponding Author:
K Singh
Department of Agricultural Meteorology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Characterization of temporal variability and trends in seasonal and annual rainfall of north central plateau land zone, Odisha

K Singh, R Paikaray, SBB Behera, A Baliarsingh, A Nanda and AKB Mohapatra

Abstract
In the recent years the important scientific challenge faced by researchers worldwide is to have a better understanding about climate change at a regional scale. However, for all the regions the changes are unequal and have localized intensity. Therefore it should be quantified at a local scale. Climate Variability is defined as variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events. Climate variability and extremes is major contributor to the recent rise in global hunger. Climate change hits the most food-insecure people the hardest. The reason for this growth centered principally on climate shock. Precipitation is one of the important climatic variables responsible for climate change and required to be studied thoroughly. Any change in rainfall pattern due to climate change can adversely affect the agricultural production. Therefore in the current study, an attempt has been made to observe the temporal rainfall variability and trend over a period of 30years (1989-2019) at regional scale for the North Central Plateau in state of Odisha. From the analysis we came into the conclusion that Ten year moving coefficient variation (CV) of seasonal rainfall of Keounjhar showed a increasing trend during *kharif* season and a constant trend during *rabi* season and Mayurbhanjh showed a increasing trend during *kharif* season and a increasing trend during *rabi* season.

Keywords: Temporal rainfall variability, seasonal and annual rainfall trend, north central plateau

Introduction
Climate describes the average weather conditions for a particular location and over a long period of time. We study the climate, its variations and extremes, and its influences on a variety of activities including human health, safety and welfare to support evidence-based decision-making on how to best adapt to a changing climate (WMO). At present, 20-80% of the inter-annual variability of crop yields is associated with weather phenomena and 5-10% of national agricultural production losses are associated with climate variability (FAO, 2019) [23]. In addition, agriculture suffers 26% of the damage and loss during climate-related disasters in developing countries. In parallel with these trends, the global demand for food will increase by 50% and, in the absence of ambitious climate action, yields may decline by up to 30% by 2050 (GCA, 2019) [11]. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external factors (external variability). Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. The term is often used to denote deviations of climatic statistics over a given period of time (e.g. a month, season or year) from the long-term statistics relating to the corresponding calendar period. In this sense, climate variability is measured by those deviations, which are usually termed anomalies. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC and WMO).
The term "Climate Variability" is often used to denote deviations of climatic statistics over a given period of time (e.g. a month, season or year) when compared to long-term statistics for the same calendar period. Climate variability is measured by these deviations, which are usually termed anomalies. Over 80% of the world’s food insecure lives in degraded environments exposed to recurrent extreme events (storms, floods, drought). In a warming world, extreme climate conditions will become more frequent and severe. A recent Food and Agriculture Organization of the United Nations (FAO) report estimated that the number of food insecure people in the world had declined from 2005 to 2014. However, the trend reversed in 2014.

From 2014–2017, the number of undernourished or food insecure people Grew from between 37 million–122 million to more than 800 million. The reason for this growth centered principally on climate shocks (GCA, 2019) [11]. This disturbing trend challenges the achievement of Sustainable Development Goal 2 (SDG) on Zero Hunger by 2030. A world that is 2 °C warmer is likely to have 189 million more food insecure people. This is an increase of around 20% compared with today (WFP, 2017). At present, 20-80% of the inter-annual variability of crop yields is associated with weather phenomena and 5-10% of national agricultural production losses are associated with climate variability (FAO, 2019) [23]. In addition, agriculture suffers 26% of the damage and loss during climate-related disasters in developing countries. In parallel with these trends, the global demand for food will increase by 50% and, in the absence of ambitious climate action, yields may decline by up to 30% by 2050 (GCA, 2019) [11]. This disturbing trend challenges the achievement of Sustainable Development Goal 2 (SDG) on Zero Hunger by 2030. At present, 20-80% of the inter-annual variability of crop yields is associated with weather phenomena and 5-10% of national agricultural production losses are associated with climate variability (FAO, 2019) [23]. In addition, agriculture suffers 26% of the damage and loss during climate-related disasters in developing countries. In parallel with these trends, the global demand for food will increase by 50% and, in the absence of ambitious climate action, yields may decline by up to 30% by 2050 (GCA, 2019) [11]. Precipitation is one of the important climatic variables responsible for climate change and required to be studied thoroughly. Any change in rainfall pattern due to climate change can adversely affect the agricultural production. Therefore in the current study, an attempt has been made to observe the temporal rainfall variability and trend over a period of 30 years (1989-2019) at regional scale for the North central plateau land zone in state of Odisha. The rainfall received in an area is an important factor in determining the amount of water available to meet various demands such as agricultural, industrial, domestic water supply and for hydroelectric power generation. The pattern and amount of rainfall (Gajbhiye *et al*., 2016) [10] are among the most vital factors that affect agricultural production and agriculture is dominant to India's economy and livelihood of its people (Kumar and Gautam, 2014) [16]. The south-west monsoon brings about 80% of the total precipitation over the country. The changes in pattern, frequency and variability of SW monsoon (Sinha & Srivastava, 2000; Seo and Ummenhofer, 2017) [22, 21] would have a significant impact on agricultural production water resource management and overall economy of the country (Saha and Mooiey, 1979) [18].

In the view of above, a number of studies have attempted to investigate the trend of climatic variables for the country. These studies have looked at the trends on country scale (Titkey *et al*., 2018, Arora *et al*., 2005, Kumar *et al*., 2010;) [14, 15] regional scales (John *et al*. 2017., Bhutiyan *et al*., 2007; 2010; Duhan and Pandey, 2013; Duan *et al*., 2017) [24, 5, 7, 6], and at the indivisual stations (Sahu *et al*., 2012, 2014, 2016; Beyene, 2015) [19-20]. In fact, local and regional scale analysis (Fischer and Ceppi, 2012; Baber and Ramesh, 2013) [9] is more relevant to devise-specific development and adaptation plans to mitigate negative effects of climate change. This article keeps on track about the qualitative assessment of temporal variability and trends in seasonal and annual rainfall of North central plateu land zone, Odisha. The trend analysis of seasonal rainfall (Panda and sahu, 2019; Singh &Srivastava, 2016) [16, 18] and other climatic variables on different spatial scales will help in construction of future climatic framework.

Hence the purpose of this study is to investigate the variability of rainfall over North central plateau land zone of Odisha, India. Characterization of temporal variability and trends in seasonal and annual rainfall is accomplished to apprehend the uncernity and variability associated with the rainfall pattern to get a better scenario at regional level for better management of agriculture and associated allied activities.

Study area
Odisha state is situated in east coast of India and agriculture plays a vital role in the state's economy which is greatly dependent on rainfall. North Cental palteu land zone consists of two districts namely Keonjhar and Mayurbhanj (except Anandpur). This zone occupy 11.5% area of the in the state of Odiaha. The climate is hot & moist sub-humid. The normal rainfall of this zone is 1534 mm. No of excess is 26 and excess 10. Maximum and minimum temperature recorded is 36.6 & 11.1 °C respectively. Broad soil group of this zone is lateritic, Red, & yellow, mixed Red & Black. Major crops in *kharif* seasonis Rice, Maize, Blackgram, Greengram, Arhar, Nijer, Ground nut. This zone is prone to occurrence of drought.

Materials and Methods
Data and Methodology The long term monthly rainfall data over a period of 30 years (1989-2019) of North Central plateau land zone was obtained. The rainfall trend analysis was conducted for all the districts of Odisha on monthly, seasonal (pre-monsoon from March to May, monsoon from June to September, post-monsoon from October to November and winter from December to February) and annual basis using the rainfall analyzer developed by ICRISAT and KMD, Kenya.

Fig 1: Study area

The mean annual rainfall of this location is 1377.4mm of which 77%occures during the *Kharif* (June-Sept) and 9% during (October-December) season. Annual rainfall varied from 1910.1 to 862.0 mm with a coefficient of variation of 20.2%. While that during *Kharif* average rainfall is 1065.4 mm and in *Rabi* 136.6mm with coefficient of variation of 22.0% and 76.1% for the respective season. During the main crop season rainfall varied between 1603.2 to 729.1 mm while that in *Rabi* the variation of rainfall is variation is 386.5 mm to 11.7mm. The number of rainy days and weekly rainfall amounts were analyzed to understand distribution of rainfall during crop season.

Table 1: Annual & Seasonal rainfall of Keonjhar

District-Keonjhar			
Variables	**Annual**	***Kharif***	***Rabi***
Rainfall amount (mm)			
Average	1377.4	1065.4	136.6
Maximum	1910.1	1603.2	386.5
Minimum	862.0	729.1	11.7
C.V	20.2%	22.0%	76.1%

Table 2: Annual & Seasonal rainfall of Mayurbhanj

District- Mayurbhanjh			
Variables	**Annual**	***Kharif***	***Rabi***
RAINFALL AMOUNT (mm)			
Average	1511.3	1145.9	147.3
Maximum	2246.1	1713.4	574.8
Minimum	995.6	718.2	17.9
C.V	19.6%	21.2%	84.1%

The mean annual rainfall of this location is 1511.3mm of which 75%occures during the *Kharif* (June-Sept) and 9% during (October-December) season. Annual rainfall varied from 2246.1 to 995.6 mm with a coefficient of variation of 19.6%. While that during *Kharif* average rainfall is 1145.9 mm and in *Rabi* 147.3mm with coefficient of variation of 21.2% and 84.1% for the respective season. During the main crop season rainfall varied between 1734.2 to 718.2 mm while that in *Rabi* the variation of rainfall is variation is 574.8 mm to 17.9mm.The number of rainy days and weekly rainfall amounts were analyzed to understand distribution of rainfall during crop season.

Distribution of seasonal rainfall

Distribution of rainfall, especially the length and frequency of occurrence of dry spell, was assessed using weekly totals. Ten year moving coefficient variation (CV) of seasonal rainfall showed an increasing trend during *kharif* season and a constant trend during *rabi* season.

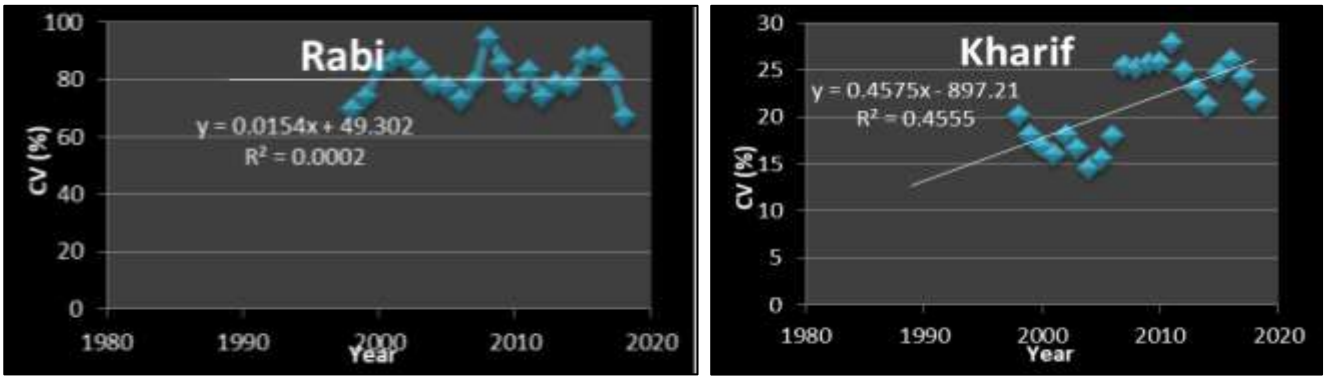

Fig 2: Trends in variability in coefficient of variation of monthly, annual and seasonal rainfall for a 10 year moving period (Keonjhar)

The coefficient of variation of seasonal rainfall for 10 year moving period shows an increasing trend in *kharif* and constant in *Rabi* seasons.

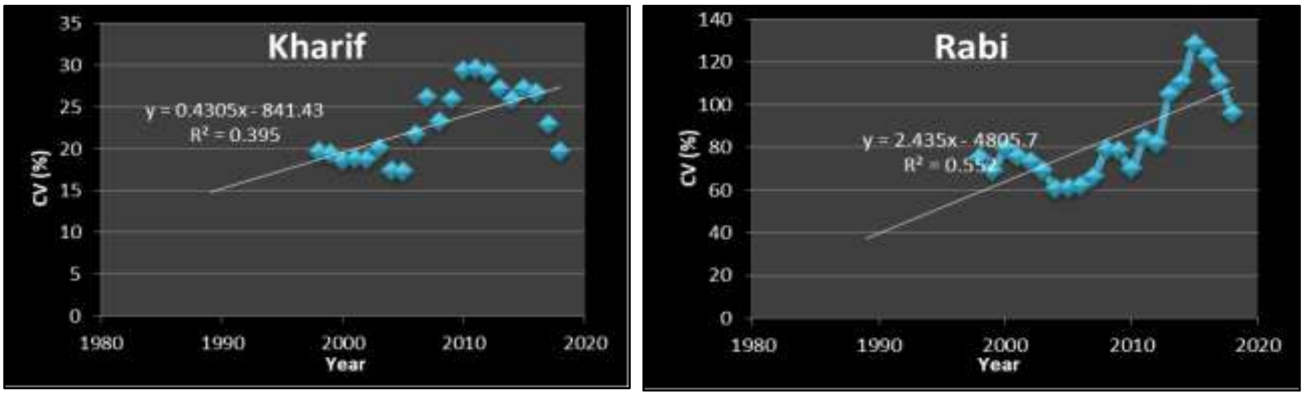

Fig 3: Trends in variability in coefficient of variation of monthly, annual and seasonal rainfall for a 10 year moving period (Keonjhar)

The coefficient of variation of seasonal rainfall for 10 year moving period shows increasing trend in both *kharif* and *Rabi* seasons.

Rainfall variability and enso events

Several studies have indicated that statistically significant inverse relationship exists between El Nino Southern Oscillation (ENSO) phenomenon and inter-annual variability of Indian monsoon (Azad & Rajeevan, 2016) [2]. Hence most seasonal forecast including ISMR predictions uses ENSO as one of the predictors (Rajeevan *et al.*2006) [2]. An important feature of ENSO is high predictability.

The occurrence and intensity of El Nino or La Nina events is computed on magnitude and direction of change of parameters such as Oceanic Nino Index (ONI), Southern Oscillation Index (SOI) and Sea Surface Temperature (SST). Based on ONI, events are defined as warm (El Nino) events when five consecutive overlapping three month periods at or above the +0.5 anomaly and at or as cold (La Nina) events if ONI is below 0.5 anomaly. The threshold is further broken down into weak (with 0.5 to 0.9 SST anomaly), moderate (1 to 1.4), strong (1.5 to 1.9) and very strong (>2) events.

Table 3: EL Nino & amp; LA Nina Years

Based on Oceanic Nino Index (ONI)			ENSO year based on SOI			ENSO year based on SST		
weak	**moderate**	**Strong**	**Weak**	**moderate**	**strong**	**weak**	**moderate**	**Strong**
El Nino								
1994-95	1991-92	1997-98	1993-94	1993-94	1991-92	1993-94	2002-03	1991-92
2004-05	2002-03	2015-16	2009-10	2009-10	1994-95	2006-07	2009-10	1997-98
2006-07	2009-10				1997-98			2015-16
					2015-16			
La Nina								
1995-96	1998-99	1988-89		1988-89	2010-11	2008-09	1998-99	1988-89
2000-01	1999-00			1998-99	2011-12		1999-00	2010-11
2011-12	2007-08			1999-00			2000-01	2011-12
2016-17	2010-11			2000-01			2007-08	
				2007-08				
				2008-09				

Rainfall during *kharif* season (June -September)in El Nino and non El Nino years and La Nina years a non La Nina years identified based on ONI, SOI, SST.

Result and Discussion

The detailed trend analysis of rainfall during the period 1989-2019 on monthly, seasonal and annual basis was carried out in the current study by Keonjhar district of Odisha state. The month of June, July, August, September is getting the leading part of the rainfall, the month August is getting highest and June and September is getting the lowest amount of rainfall. On an average July is getting 300mm of rainfall. The annual rainfall of the location is deviating with a Percentage change in annual and seasonal rainfall was also determined to show the change in trend. Ten year moving coefficient variation (CV) of seasonal rainfall showed a increasing trend during *kharif* season and a constant trend during *rabi* season.The descriptive statistics of rainfall e.g Range, Median, Deviation, Variance, Std Error, Kurtosis, Skewness, Coefficient of variation (CV %) are discussed. It is found that CV seems to varying from 29.8 to 244.8% for August and December month respectively. The skewness and kurtosis is highest for month of December for Keonjhar.

Table 4: Descriptive Statistics for Keonjhar

Month	Mean	Min	Max	Range	Median	Std Dev	Variance	Std Error	Kurtosis	Skewness	Count	Conf lvl (95%)	CV (%)
Jan	11.1	0.0	89.8	89.8	1.0	22.6	513	4.1	5.6	2.5	30	0.26	204.4
Feb	11.8	0.0	81.8	81.8	3.5	18.7	348	3.4	6.6	2.4	30	0.21	157.5
Mar	16.4	0.0	110.9	110.9	10.5	23.9	571	4.4	8.6	2.7	30	0.27	146.1
Apr	40.8	0.0	133.3	133.3	36.0	35.1	1232	6.4	0.5	1.0	30	0.40	86.1
May	95.4	22.6	197.9	175.4	93.9	45.7	2092	8.3	-0.6	0.4	30	0.52	47.9
Jun	227.6	85.2	545.4	460.3	201.4	100.0	10007	18.3	3.0	1.5	30	1.15	43.9
Jul	300.0	101.7	444.3	342.6	299.2	90.3	8150	16.5	-0.6	0.0	30	1.03	30.1
Aug	310.0	148.0	510.1	362.2	309.8	92.4	8530	16.9	-0.4	0.2	30	1.06	29.8
Sep	227.7	91.1	567.0	475.9	214.0	100.1	10016	18.3	3.5	1.5	30	1.15	43.9
Oct	112.2	10.1	380.5	370.3	93.9	98.8	9754	18.0	1.8	1.5	30	1.13	88.0
Nov	18.0	0.0	94.2	94.2	4.1	26.5	702	4.8	2.6	1.8	30	0.30	147.6
Dec	6.4	0.0	62.6	62.6	0.0	15.7	247	2.9	6.6	2.7	30	0.18	244.8
Annual	1377.4	862.0	1910.1	1048.1	1362.7	277.9	77249	50.7	-0.5	0.2	30	3.18	20.2
Kharif	1065.4	729.1	1603.2	874.1	1054.9	234.4	54966.6	42.8	0.0	0.7	30	2.68	22.0
Rabi	136.6	11.7	386.5	374.8	108.0	103.9	10805.1	19.0	0.3	1.0	30	1.19	76.1

Table 5: Descriptive Statistics for Mayurbhanjh

Month	Mean	Min	Max	Range	Median	Std Dev	Variance	Std Error	Kurtosis	Skewness	Count	Conf lvl (95%)	CV (%)
Jan	14.0	0.0	88.2	88.2	3.0	22.1	489	4.0	4.2	2.1	30	0.25	158.1
Feb	14.7	0.0	65.9	65.9	5.6	20.2	410	3.7	0.6	1.4	30	0.23	137.3
Mar	25.0	0.0	106.7	106.7	18.9	26.4	698	4.8	1.9	1.4	30	0.30	105.8
Apr	50.5	0.0	172.1	172.1	44.2	40.2	1619	7.3	1.5	1.2	30	0.46	79.7
May	114.0	35.9	229.7	193.8	109.2	48.0	2308	8.8	-0.1	0.6	30	0.55	42.2
Jun	253.7	69.7	666.8	597.1	229.9	115.8	13404	21.1	4.4	1.6	30	1.33	45.6
Jul	310.5	119.1	541.3	422.2	288.1	105.5	11138	19.3	-0.2	0.5	30	1.21	34.0
Aug	327.9	157.0	565.8	408.8	342.5	96.4	9300	17.6	0.1	0.1	30	1.10	29.4
Sep	253.8	66.5	471.0	404.6	253.8	92.9	8636	17.0	0.2	0.3	30	1.06	36.6
Oct	122.3	15.1	574.8	559.7	85.4	120.1	14417	21.9	6.0	2.2	30	1.37	98.2
Nov	18.6	0.0	176.1	176.1	7.7	33.9	1149	6.2	16.6	3.8	30	0.39	182.0
Dec	6.4	0.0	47.7	47.7	0.0	12.7	162	2.3	3.7	2.1	30	0.15	199.2
Annual	1511.3	995.6	2246.1	1250.6	1487.9	296.0	87631	54.0	0.0	0.5	30	3.39	19.6
Kharif	1145.9	718.2	1713.4	995.2	1102.0	242.6	58871.5	44.3	-0.3	0.4	30	2.78	21.2
Rabi	147.3	17.9	574.8	557.0	101.3	123.9	15359.3	22.6	3.5	1.6	30	1.42	84.1

The detailed trend analysis of rainfall during the period 1989-2019 on monthly, seasonal and annual basis was carried out in the current study by Mayurbhanjh district of Odisha state. The month of June, July, August, September is getting the leading part of the rainfall, the month August is getting highest and June is getting the lowest amount of rainfall. On an average July is getting 310.5mm of rainfall. The annual rainfall of the location is deviating with a Percentage change in annual and seasonal rainfall was also determined to show the change in Trend. Ten year moving coefficient variation (CV) of seasonal rainfall showed an increasing trend during *kharif* season and an increasing trend during *Rabi* season.

The descriptive statistics of rainfall e.g. Range, Median, Deviation, Variance, Std Error, Kurtosis, Skewness, Coefficient of variation (CV %) are discussed. It is found that CV seems to varying from 29.4 to 199.2% for August and December month respectively. The skewness and kurtosis is highest for month of December for Mayurbhanjh.

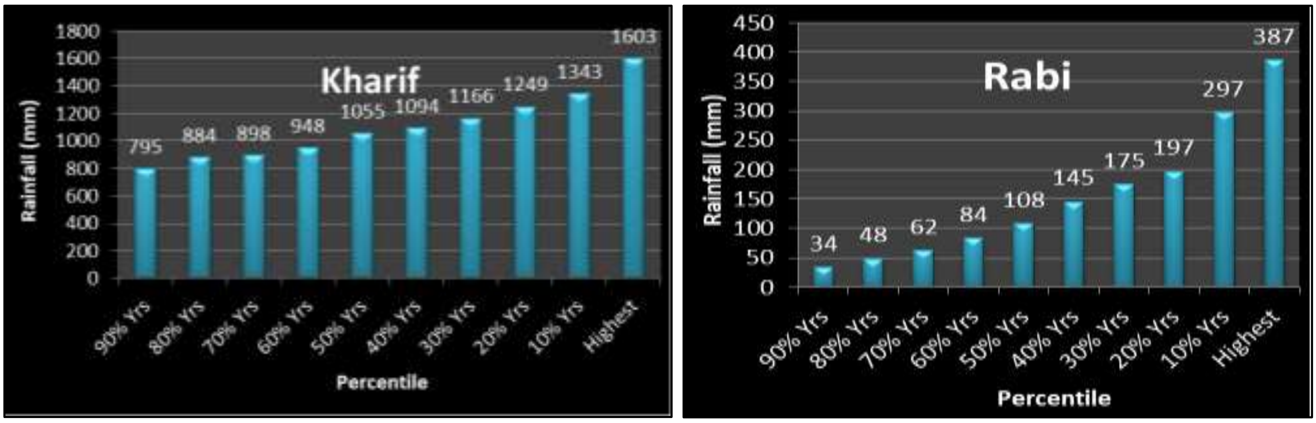

Fig 4: Seasonal percentiles of Rainfall Mayurbhanjh

From the seasonal percentiles of rainfall it is observed that in *kharif* 90% of the years are getting rainfall more than 700mm of rainfall but in *Rabi* 90% of the years are getting only 34mm of rainfall.

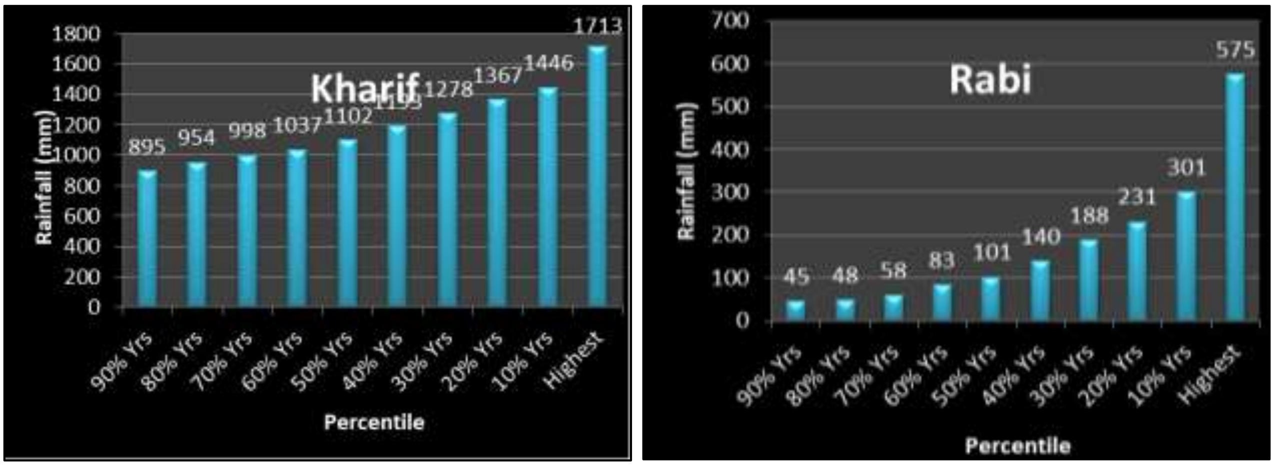

Fig 5: Seasonal percentiles of Rainfall for Keonjhar

From the seasonal percentiles of rainfall it is observed that in *kharif* 90% of the years are getting rainfall more than 831mm of rainfall but in *Rabi* 90% of the years are getting only 45mm of rainfall.

Conclusion

Agriculture in Odisha is mainly rainfed and affected by rainfall anomalies, Rice being main crop is affected by vagaries of climatic as well as rainfall variability. North Central Plateau is of Odisha needs special attention for the formation of mitigation strategies in view of this varying climatic situation.

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