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Climatic variability in Bhadrak district of Odisha and its characterisation

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Abstract
Climate variability and characterisation is very useful for understanding the current occurrence of the climate. Block wise historical rainfall data of 23 years (1995 to 2017) of Bhadrak District were collected and processed by using Weather cock software which revealed that the total mean annual rainfall of the district is 1431 mm. CV of annual rainfall in different blocks varies from 21-33%. Highest mean monthly rainfall in the district was in the month of July (286 mm) and December was the month of the lowest rainfall (4mm). Bhadrak receives almost 70% of mean annual rainfall during SW monsoon. Bhandaripokhari and Tihidi block had the highest of drought frequency (26%) followed by Dhamnagar block (21%). At 75% probability Bhadrak received 1152 mm rainfall, which is good amount of rainfall for crop production. Mean annual maximum temperature of Bhadrak district was 33ºC and minimum temperature was 22.4ºC. Hottest month in the district is May (37.5ºC) and January was the coldest month (13.6ºC). The number of occurrence of warm days in an increasing trend, while the occurrence of cold days was in decreasing trend

Keywords: Weather cock, CV, SW monsoon, trend

Introduction
Climate is a very important part of the general environment where organisms are grown, having a great impact on them. Recent observational studies showed that the temperature extremes, particularly those derived from minimum temperature, have significantly increased over the 20th century and will continue to increase throughout the 21st century. Each year there are climatic events that represents risk to people and organization. Most organization has practice and strategies in place to deal with this routine climate variability. For these organizations, climate variability will continue to raise challenges and risk that have to be managed. Around 60 percent of the Indian agriculture is rain dependent, distress prone and vulnerable to climate. Climatic variability, particularly rainfall is the major factor influencing the agricultural productivity and sustainability in the tropics. Odisha (17.49´N to 22.34´N and 81.27´E to 87.29´E), an eastern Indian province, is mainly an agrarian state where about 70 percent of the population is engaged in agricultural activities and 50 percent of the state's economy comes from agricultural sector. Bhadrak district falls under North Eastern Coastal Plain Zone of Odisha which covers 29 blocks of Balasore, Bhadrak and Keonjhar districts. The total geographical area of the district is 2, 50,000 ha. The net sown area in the district is 1, 73,000 ha. The total cultivable land in the district is 1, 74,063ha and irrigated area is 1, 11,000ha. Lying on the coastline of the state of Odisha, the topography of the district of Bhadrak is principally affected by the sea.

Materials and Methods
Rainfall and Temperature analysis
Climatic data of twenty three year (1995 to 2017) have been collected for climatic variability and characterisation in the study area. This has been done for the each block of the Bhadrak district. In this study 'Weather Cock' software has been used for weather data analysis. The Weather Cock software contains 26 numbers of modules, which are related toagro climatic parameters. Annual, Seasonal and Monthly rainfall, Meteorological drought frequency, Incomplete Gamma Probabilities, Seasonal and monthly mean temperature and Extreme temperature frequency were calculated by using Weather cock.

A day with rainfall amount equal or more than 2.5 mm was considered as a rainy day according to India Meteorological Department for Indian region.

Results and Discussion

Rainfall characteristics and rainfall variability

Annual Rainfall and rainy days

The mean annual rainfall of the district was found to be 1431 mm (Table 1). Highest rainfall was received in the block Basudevpur (1849mm) while Bhandaripokhari block received the lowest amount of rainfall (1250mm).Variability of the district annual rainfall was 21% to 33% (Table 1). Thus blocks having CV less than 25% can be considered to be receiving rainfall that is highly dependable. The blocks coming under this category are Bhadrak, Bonth and Chandbali. The remaining four blocks (Bhandaripokhari, Basudevpur, Dhamnagar, and Tihidi) are having CV greater than the threshold indicating that there is high variability in the amount of rainfall received by these blocks over years. So, a greater part of the district has the risk in rainfed farming.

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.

Table 1: Block wise mean annual rainfall with standard deviation and CV (%)

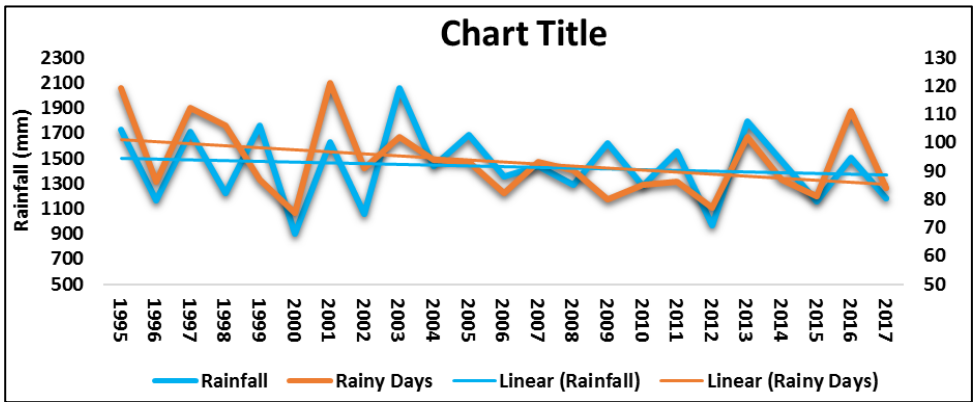
BLOCK	MEAN(mm)	SD	CV (%)
Bhadrak	1461	308	21
Bhandaripokhari	1250	362	28
Basudevpur	1849	575	31
Bonth	1320	320	24
Chandbali	1500	370	24
Dhamnagar	1330	445	33
Tihidi	1308	385	29
District	1431	396	27

Year wise annual rainfall andrainy days

Highest amount of rainfall (2052 mm)was received in 2003 and lowest (901 mm) in 2000. But highest number of rainy days (121 days) ware recorded in 2001 and lowest (75days) in 2000 (Table 2). From the graph it was observed that number of rainy days was in decreasing trend(Graph 1).

Table 2: Year wise annual rainfall and rainy days

YEAR	RF(Mean)	Rainy Days
1995	1723	119
1996	1158	86
1997	1705	112
1998	1221	106
1999	1750	87
2000	901	75
2001	1630	121
2002	1055	91
2003	2052	102
2004	1437	94
2005	1686	93
2006	1350	82
2007	1424	93
2008	1285	90
2009	1619	80
2010	1277	85
2011	1549	86
2012	966	77
2013	1794	102
2014	1477	87
2015	1158	81
2016	1506	111
2017	1183	84
SD	293	13
CV (%)	20	14



Graph 1: Year wise annual rainfall and rainy days

Monthly Rainfall

Highest mean monthly rainfall in the district was in the month of July (286 mm) (Table 3). It was followed by August with 271 mm and September 238 mm. December was the month of the lowest rainfall (4mm). Monthly rainfall variability was maximum in March (48%) followed by December (29%), while minimum in the month of June and July (11%) followed by August (13%). Four out of twelve months namely, January, June, July and August had low variability (<20%) of monthly rainfall. Monthly rainfall variability was high (>20%) in the month of February, March, April, May, September, October, November and December (Table 3). Monthly rainfall varies from region to region and the highest rainfall giving month may be July or August.

Rainfall characteristics of the Cauvery basin shows that, the coefficient of variation is highest in July (100%), followed by June (97.96%), December (97.96%) and January (78.48%) and the least during October (15.19%) and September (23.77%). Significant relationship between SD and CV has been observed during the months of highest rainfall (July and June) (Sawant S. *et al*. 2015) [6].

Table 3: Mean monthly rainfall (mm) with standard deviation (mm) and CV (%)

Block	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bhadrak	9	14	37	54	160	238	347	345	326	275	36	4
Bhandaripokhari	10	9	9	32	95	195	269	242	223	141	18	3
Basudevpur	11	15	19	49	116	220	289	272	244	188	29	5
Bonth	11	14	14	32	97	184	288	269	225	157	21	4
Chandbali	12	6	19	33	91	213	283	307	264	221	44	3
Dhamnagar	7	7	17	46	111	187	267	266	200	193	22	2
Tihidi	10	11	16	48	117	178	249	239	226	177	31	2
District Mean	10	12	18	42	113	198	286	271	238	184	26	4
SD	2	3	9	10	23	22	31	35	41	44	6	1
CV (%)	15	26	48	22	20	11	11	13	17	24	25	29

Seasonal Rainfall: The district average SW monsoon rainfall is 1009mm±281 mm. Basudevpur block had the maximum (1257 mm) and Tihidi block had minimum (893 mm) of monsoon rainfall. Bhadrak receives almost 70% of mean annual rainfall during SW monsoon(Table 4). It was thus clear that SW monsoon accounts for a major part of rainfall distribution out of all the seasons. During SW monsoon, variability of rainfall was 24-33%. Lowest (21 mm) amount of rainfall was received during winter but maximum variability (125%) was observed during this period. Rainfall variability varied from 81% to 117% during post-monsoon and 41% to 72% in summer season (Table 4). The CV of seasonal rainfall except South west monsoon is higher than the threshold (50% for seasonal rainfall).

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) [4].

In a study conducted at Directorate of Water Management by Mandal *et al*., 2013 [3] for Daspalla region of Odisha, it was observed that total annual rainfall in Daspalla region was 1509.2 mm with 14.8% CV. SW monsoon delivers about 75.7% of annual rainfall, winter season contributes 3.1%, and 10.8% & 10.4% of the total annual rainfall occurred during pre- and post-monsoon season, respectively.

Table 4: Mean seasonal rainfall with standard deviation and CV (%)

Block	Monsoon			Postmonsoon			Winter			Summer		
	Mean (mm)	SD (mm)	CV %	Mean (mm)	SD (mm)	CV %	Mean (mm)	SD (mm)	CV %	Mean (mm)	SD (mm)	CV %
Bhadrak	1026 (70%)	253	24	223 (15%)	230	103	26 (1.7%)	30	114	185 (12%)	76	41
Bhandaripokhari	930 (74%)	256	27	163 (13%)	170	104	19 (1.5%)	27	138	137 (10%)	84	61
Basudevpur	1257 (68%)	376	29	315 (17%)	281	89	23 (1.2%)	27	116	251 (11%)	154	61
Bonth	967 (73%)	240	24	183 (13%)	172	93	25 (1.8%)	31	124	143 (10%)	89	62
Chandbali	1069 (71%)	299	28	269 (17%)	220	81	18 (1.2%)	21	119	143 (9%)	78	54
Dhamnagar	921 (69%)	246	26	218 (16%)	256	117	14 (1%)	22	155	176 (13%)	127	72
Tihidi	893 (68%)	321	36	211 (16%)	148	70	21 (1.6%)	36	154	182 (14%)	75	40
District Mean	1009 (70%)	284	27	226 (15%)	211	93	21 (1.4%)	27	131	174 (12%)	97	55

Meteorological drought frequency

Probability of occurrence of drought in the district was 8% to 26% (Table 5), which was highest in Bhandaripokhari and Tihidi block (26%) followed by Dhamnagar (21%). Basudevpur and Chandbali block had probability of lowest frequency of drought (8%).

Kumar *et al.* (2009) [1] analysed 44 years of rainfall (1961-2004) in Tarai region of Uttarakhand on annual, seasonal, monthly and weekly basis and investigated the occurrence of meteorological drought for sustenance of agricultural productivity in hilly regions of Uttarakhand. They have found that meteorological drought assessment based on weekly basis is very important in rainfed areas. From study, it was also revealed that there is a need to adopt measures for assured irrigation in the region to mitigate the effect of drought during the pre-monsoon and post-monsoon crops, and a provision of supplemental irrigation or in-situ moisture conservation measures to meet dry spells during monsoon season.

Table 5: Meteorological drought frequency

Block	Frequency(% year)
Bhadrak	13
Bhandaripokhari	26
Basudevpur	8
Bonth	13
Chandbali	8
Dhamnagar	21
Tihidi	26

Probability of annual rainfall

Probability analysis of rainfall offers a better scope for predicting the minimum assured rainfall to help in crop planning. The amount of rainfall at different probability levels (10-90%) called assured rainfall have been computed for each standard week by fitting Incomplete Gamma Distribution model. In this study, probability analysis of block level annual rainfall was made at three levels of probability, 90%, 75% and 50%.

The incomplete gamma distribution probability analysis indicated that, the 90% dependable rainfall was below 1100 mm in almost all blocks except Basudevpur block (1222mm). Minimum amount of 90% probable rainfall was in Dhamnagar block (754mm). At 75% probability, rainfall was above 1300 mm in one blocks, namely, Basudevpur (1486mm) (Table 6). The rainfall was below 1100 mm for the blocks, namely, Bonth, Tihidi, Bhandaripokhari and Dhamnagar. At 50% probability, rainfall was above 1200mm in all blocks. Highest rainfall was in Basudevpur block (1821mm) at 50% probability and lowest in Bhandaripokhari block (1214mm).

Table 6: Rainfall (mm) at three probability

Block	90% Probability	75% probability	50% probability
Bhadrak	1086	1245	1439
Bhandaripokhari	827	998	1214
Basudevpur	1222	1486	1821
Bonth	940	1099	1296
Chandbali	1045	1234	1470
Dhamnagar	754	958	1225
Tihidi	861	1048	1286
District	962	1152	1393

Thermal characteristics

Mean monthly temperature

Mean annual maximum temperature of Bhadrak district was 33ºC and minimum temperature was 22.4ºC **(Table 7)**. Hottest month in the district is May (37.5ºC) followed by April (37.1ºC). January was the coldest month (13.6ºC) followed by December (14.4ºC). A fall in temperature is observed towards the end of November that continues till February. The temperature starts rising from April onwards.

Table 7: Mean monthly maximum and minimum temperatures (ºC)

Month	Tmax	Tmin
January	27.1	13.6
February	30.5	16.9
March	34.3	21.2
April	37.1	24.1
May	37.5	25.3
June	34.9	25.5
July	32.2	25.1
August	31.7	25.3
September	31.9	25.1
October	31.5	23.2
November	30.0	18.8
December	27.9	14.4
Annual	33.0	22.4

Mean seasonal temperature

In summer maximum temperature remain highest (36.3ºC) and in winter minimum temperature remain lowest 14.9ºC. Minimum temperature remained above 25ºC during summer and monsoon season (Table 8).

During SW monsoon, the mean seasonal maximum and minimum temperatures of Bhadrak district were 32.6ºC and 25.2ºC respectively. Maximum and minimum temperatures were lowest in winter season i.e. 28.5ºC and 14.9ºC, respectively (Table 8).

Pasupalak (2015) [5] reported that the entire coastal districts of Odisha are warm in SW monsoon season and post monsoon season. Kandhamal and Boudh are two coldest district and minimum temperature even in summer.

During summer, the entire western, southern and two central district namely Angul and Dhenkanal are in the hottest zone exceeding 38ºC.

Table 8: Mean seasonal maximum and minimum temperatures (ºC)

Season	Tmax	Tmin
SW Monsoon	32.6	25.2
Post Monsoon	30.7	21
Winter	28.5	14.9
Summer	36.3	25.5

Extreme temperature frequency

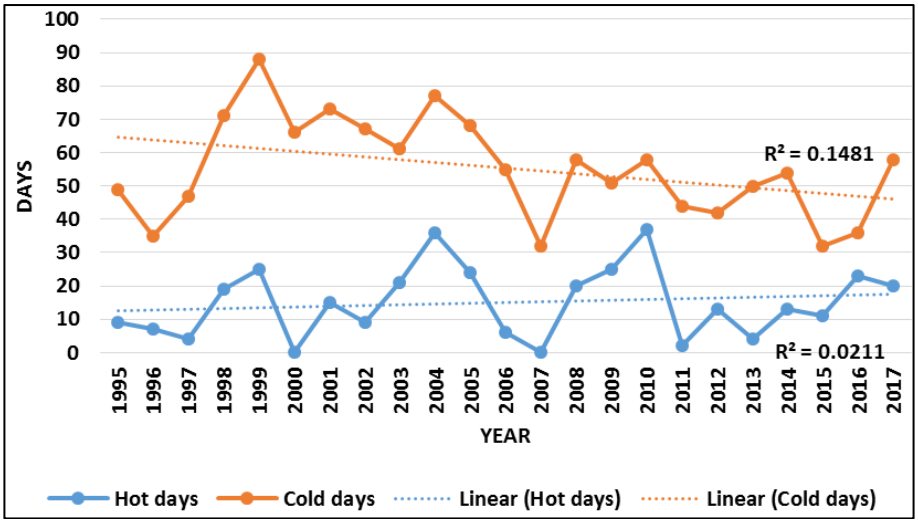
Extreme temperature frequency (≥40ºC) varied from 2 days (2011) to 37 days (2010) during the period from 1995 to 2017 (Table 9) and frequency of (≤15ºC) varied between 31 days in 2015 to 88 days in 1999. From the graph it was observed that number of occurrence of hotter days was in increasing trend, while the frequency of occurrence of cold days was in decreasing trend (Graph 1).

Kumar *et al*., (2014) [2] in a study conducted by CESCRA, IARI observed that during the monsoon (kharif) season, mean

seasonal *minimum temperatures* increased at a rate of 0.18 and 0.07 °C in every 10 years in Mewat and Dhar districts, respectively. In Raigad they increased at a rate of 0.04°C per 10 years. On the other hand in Ganjam the mean seasonal minimum temperatures have decreased at a rate of 0.1 °C in every 10 years period.

Table 9: Extreme temperature frequency (days)

Year	Highest temp.	Hot Days	Lowest temp.	Cold Days
1995	41.9	9	10.2	49
1996	41.9	7	10.2	35
1997	41.5	4	10	47
1998	45.1	19	8	71
1999	42.3	25	8	88
2000	38.8	0	7.8	66
2001	41.5	15	8	73
2002	45.7	9	8.5	67
2003	43	21	8	61
2004	44.6	36	8	77
2005	43.6	24	9.8	68
2006	40.4	6	8.8	55
2007	39.4	0	9	32
2008	42.2	20	12	58
2009	44	25	11	51
2010	44.6	37	10.9	58
2011	40.3	2	9.7	44
2012	45.5	13	9.7	42
2013	40.7	4	10.4	50
2014	41.8	13	10.4	54
2015	43.7	11	10.6	31
2016	43.8	23	11.5	36
2017	43	20	9.5	58



Graph 2: Occurrence of hot and cold days

Conclusion

Rainfall is the important element of Indian economy. Although the monsoons effect most part of India, the amount of rainfall varies from heavy to scanty on different parts. There is great regional and temporal variation in the distribution of rainfall. The overall mean rainfall of the Bhadrak district was 1431mm.Highest rainfall was received in the block Basudevpur (1849mm) while Bhandaripokhari block received the lowest amount of rainfall (1250mm). Monsoon season contributing the highest quantity (70%) to the annual rainfall. The seasonal C.V. was found lowest in Monsoon (24-33%) indicating rainfall was most reliable. Probability of occurrence of drought was highest in Bhandaripokhari and Tihidi block (26%). There is a need to adopt measures for assured irrigation in the region to mitigate the effect of drought during the pre-monsoon and post-monsoon crops, and a provision of supplemental irrigation or in-situ moisture conservation measures to meet dry spells during monsoon season. Occurrence of warm days in winter is gradually increasing. Using long term local weather data for identifying consequences of climate change like extreme weather events and its effects on local environment needs immediate attention for effective agricultural planning and management. Screening and identification of suitable varieties including local ones tolerant to high temperature and subsequent breeding works for development of new varieties needs urgent attention of researchers.

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