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Agro-climatic characterization and assessment of sowing window of rice-pulse cropping system over mid central table land zone of Odisha

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Abstract

The present study was undertaken to determine the sowing window of *kharif* rice and *rabi* pulses in different blocks of Dhenkanal district of mid central table land zone of Odisha based on the rainfall probability, temperature and length of growing period. The sowing window of *kharif* rice in Dhenkanal district was found between 23-24 Standard meteorological week (SMW) except Kankadahad, when the conditional probabilities of wet followed by wet (Pww) was >50%. In medium land condition, sowing of pulses (green gram and black gram) is done in 40 SMW in Kankadahad, 41 SMW in Bhuban, Dhenkanal sadar, Hindol, Kamakhyanager, Parajang and 42 SMW in Odapada by zero till method. In low land condition of Dhenkanal, *rabi* pulses can be sown in between 44-45 SMW in Dhenkanal sadar and Hindol by zero till method after rice harvest and in between 40-41 SMW in Kankadahad, 41-42 SMW in Bhuban, Dhenkanalsadar, Kamakhyanager and 42-43 SMW in Odapada and Parajang with the utilization of residual soil moisture by *paira* method i.e. 15-20 days before the harvest of rice. The average weekly minimum temperature is 20-24 °C and chances of occurrence of wet weeks are more than 30% at 20 mm threshold limit of rainfall which is optimum for seeding and germination of pulses in that sowing week.

Keywords: LGP, *rabi* pulses, rice-fallow, SMW

Introduction

Timely planting under adequate soil moisture is the key to realize higher productivity in rice and pulses. Timely planted crop takes care of residual soil moisture efficiently, and robust root growth of the crop could resist soil moisture stresses that might come in the latter crop growth stages. Besides the constraints observed inherent to rice fallows, growing of profitable (second) crop cultivation, suitable strategies for alteration in sowing windows of both *kharif* and *rabi* crop could be a boon for conserving natural resources and higher productivity realization (Kar *et al.*, 2004; Praharaj *et al.*, 2018) [6, 13]. The time of *rabi* sowing in rice-fallows at a particular place depends on the time of harvesting of rice, which in turn depends upon either duration of the rice variety or time of transplanting (Singh *et al.*, 2016) [18]. So, there is need for the criterion to be used in identifying the onset dates for the ongoing season to enable the farmers to better plan their seasonal cropping activities (Bussmann *et al.*, 2016) [2].

Materials and Methods

The study was conducted in Dhenkanal district of Odisha located between 85°58'E to 86°20'E longitude and 20°29'N to 21°11'N latitudes under mid central table land zone of Odisha covering eight number of blocks namely Bhuban, Dhenkanal sadar, Gondia, Kamakhyanager, Hindol, Kanakadaahad, Parajang and Odapada (Fig. 1). All the weather data like morning and evening relative humidity (RH₁, RH₂), bright sunshine hours (BSH), wind speed (WS) and evaporation (E) has been collected from the Department of Agricultural Meteorology, OUAT, and Bhubaneswar for the period 1995-2017 (23 years). Block wise rainfall data of Dhenkanal has been obtained from SRC site of Govt. of Odisha for the same period.

Rain fall characterization

Mean value of annual, seasonal, monthly and weekly rain fall and rainy day and also normal daily rainfall were found out by analyzing rainfall block wise over a period of 23 years. Block wise daily rainfall data were collected from Special Relief Commissioner (SRC), Odisha. In this study the 'Weather Cock' software was used for weather data analysis.

Spatial and temporal variability of rainfall

Mean annual, seasonal, monthly, weekly and daily rainfall and rainy day and variability of rainfall were found out by analyzing block wise daily rainfall data over a period of 23 years using Weather cock. "Rainy Day.exe" module was used to analyze the rainfall data. Standard deviation (SD) and Co-efficient of variance (CV) were calculated by using statistical equation.

Interpolation techniques

The inverse distance weighting interpolator assumes that each input point has a local influence that diminishes with distance. It weights the points closer to the processing cell greater than those further away. A specified number of points or all points within a specified radius can be used to determine the output value of each location. Use of this method assumes the variable being mapped decreases in influence with distance from its sampled location. This interpolation technique is used for the mapping of seasonal rainfall distribution of Dhenkanal district by using "Arc GIS" software.

Markov chain probability model for dry and wet spell analysis

Simple criterion related to sequential phenomenon like dry and wet spell was used for analyzing rainfall data to obtain specific information needed for crop planning and for carrying out agricultural operations. In this study, weekly rainfall values have been computed from daily data series and were used for estimation of initial, conditional probabilities and consecutive dry and wet spell analysis based on 'Markov chain probability model'. In this method, 20 mm or more rainfall in a week is considered as wet week otherwise dry as the previous researchers (Dash and Senapati, 1992; Joseph *et al.*, 2017)^[4, 5], who used 20 mm as the threshold value. Initial, conditional probabilities and consecutive dry and wet spell analysis for 52 standard meteorological weeks (SMW) are made by using equations from 1-10.

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

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

P(DW) = probability of a dry week preceded by a wet week

Consecutive dry and wet week probabilities

$$P(2D) = P(DW1) \times P(DDW2) \quad (\text{Eq. 7})$$

$$P(3D) = P(DW1) \times P(DDW2) \times P(DDW3) \quad (\text{Eq. 8})$$

$$P(2W) = P(WW1) \times P(WWW2) \quad (\text{Eq. 9})$$

$$P(3W) = P(WW1) \times P(WWW2) \times P(WWW3) \quad (\text{Eq. 10})$$

Where,

P(2D) = probability of 2 consecutive dry weeks starting with the week

P(DW1) = probability of the first week being dry

P(DDW2) = probability of the second week being dry, given the preceding week being dry

P(3D) = probability of 3 consecutive dry weeks starting with the week

P(DDW3) = probability of the third week being dry, given the preceding week dry

P(2W) = probability of 2 consecutive dry weeks starting with the week

P(WW1) = probability of the first week being wet

P(WWW2) = probability of the second week being wet, given the preceding week being wet

P(3W) = probability of 3 consecutive wet weeks starting with the week

P(WWW3) = probability of the third week being wet, given the preceding week wet.

Analysis of air temperature

Normal temperature

Seasonal, monthly, weekly normal temperatures (T_{\max} and T_{\min}) were calculated by using the software "Weather Cock" (WC). The input data file comprised of daily T_{\max} and T_{\min} over the period of given years which were taken from NASA power software. The module of WC named as "Normal.exe" was used to derive seasonal and monthly normal temperature and the annual temperature was derived by computing the total monthly normal temperature.

Soil characterization

Soil land type and soil texture plays a vital role in deciding the type and variety of crop to be grown in that area. Textural analysis is done for determine the percentage of sand, slit and clay by Bouyoucos hydrometer and the soil type were decided by using the textural triangle which needed for determining the available water holding capacity (AWHC).

Length of growing period (LGP) assessment

LGP = [Duration of rainy season in days + Post monsoon and winter rainfall (mm) + AWHC (mm/m) / average evaporative demand of the atmosphere per day from agricultural field in post-monsoon and winter season] (Sattar *et al.*, 2013)^[17].

Average evaporative demand of the atmosphere in post monsoon and winter period from agricultural field in

Dhenkanal was taken as 3.8 mm per day. As per soil characteristics, the available water holding capacity (AWHC) per one meter depth for Dhenkanalsadar and Kamakhyanagar soils was 150 mm/m. The AWHC of Bhuban, Gondia, Hindol, Kankadahad, Odapada and Parajang soils were taken as 100 mm/m.

Determination of sowing window

Sowing window of *kharif* paddy was determined basing on the onset and probability of rainfall, weekly rainfall CV, the soil land and texture type after that from the LGP and duration of ruling rice variety of different blocks the pulse sowing window is adjusted.

Thresholds of rainfall for deciding sowing window of *kharif* paddy and *rabi* pulses using initial and conditional probabilities

For the district Dhenkanal to decide the sowing window of *kharif* paddy in the threshold limit of 20 mm per week, the land preparation was taken when the initial probability (P_w) of rainfall in the pre monsoon shower is $>30\%$ and the average weekly rainfall is 20-40 mm. The sowing operation is done when the conditional probability of wet followed by wet week (P_{ww}) is more than 50%. The average weekly threshold limit of CV in the rainy season should be less than 150% which means there is high dependability of rainfall in the rainy season. During *rabi* period chances of occurrence of wet weeks are more than 30% and consecutive wet weeks are preferable for sowing of *rabi* pulses like green gram and black gram. The weekly CV of rainfall during the sowing period of *rabi* crop varies from 83 to 175%. During this crop season the CV is more than threshold limit of 50%. This indicates less dependability of rainfall during this period.

For the purpose of sowing, we have applied Markov Chain model by choosing 10 and 20 mm per week as threshold limits. These threshold levels were considered as adequate for the crop activities such as land preparation (10 mm), crop planting or sowing (20 mm). According to Reddy (2008) [16], if a given week 'i' of a given year received more than 20 mm/week at more than 50% (W/W) threshold level, then week 'i' is the right time for planting.

The threshold levels for CV for any interpretation are < 25 , < 50 , < 100 and $< 150\%$ for annual, seasonal, monthly and weekly rainfall, respectively. If the CV is within the threshold limit of variability, it is considered that the rainfall is highly dependable and vice-versa (Manorama *et al.*, 2007) [9].

Results and Discussion

Climatic characterization

Mean annual rainfall for Dhenkanal district was 1367 mm while average number of rainy days were 64. Variability of annual rainfall among the all blocks of Dhenkanal district varied from 18 to 25% except Gondia block while CV of annual rainy days varied from 12 to 17% except Kankadahad (Pasupalak, 2015) [12]. Mean seasonal rainfall (1055 mm) and rainy days (50 days) were the highest in SW monsoon followed by post-monsoon. As a whole Dhenkanal received 77% of the mean annual rainfall during SW monsoon, which indicates all the blocks received sufficient amount of rainfall for *kharif* paddy except Parajang (Fig. 2) and 8% during post-monsoon period which creates a better climatic condition of pulse production with the residual soil moisture after the harvest of *kharif* paddy in the fallow land but the post-monsoon rainfall was scanty for Kankadahada and Parajang

(Fig. 3). So pulses can be cultivated in rice fallow land with the better utilisation of moisture or with assured irrigation.

Probability of occurrence of two to three consecutive dry weeks was $>90\%$ from week 1 to 15 and also from week 45 to 52 standard meteorological week (SMW) at rainfall limit of 20 mm, so sowing of *rabi* pulses should be done before 45 SMW. Probability of occurrence of two consecutive wet weeks was $>50\%$ from week 25 to 37. The range of probability of wet week in these weeks varied from 50 to 70%, so *kharif* rice transplanting was done from 26 SMW (Chand *et al.*, 2011) [3]. The mean weekly minimum temperature at the sowing time i.e. from 40-44 SMW was 20-24 °C (Table 1), which was optimum for sowing activity of pulses like green gram and black gram (Umata, 2018) [19]. The post-monsoon mean maximum and minimum temperature were 27.8 °C and 18.9 °C (Fig. 4), which was optimum for pulse cultivation in the rice fallow area. The onset of monsoon was in between 14-18 June (Table 2) and the cessation of monsoon was in between 8-13 October in the district. The rainy day was calculated as the day from onset of monsoon to cessation of monsoon. It was 115-120 days for most of the blocks (Table 2). It was the maximum (122 days) in Hindol block and the minimum (113 days) in Odapada block. Most of the blocks had 106-133 mm post-monsoon and winter rainfall. Parajang had the minimum (99 mm) and Hindol had the maximum (165 mm) post-monsoon and winter rainfall (Table 3). The post-monsoon mean maximum temperature and minimum temperature was 27.8 and 18.9 (Fig. 4), respectively, which was optimum for the cultivation of *rabi* pulses in the rice fallow condition.

Soil characterization

Raychaudhuri *et al.* (1963) [15] observed that, the soils most suited to rice cultivation are heavy soils and clays or clay loams. Such soils, with high water- holding capacity, produce higher rice yields and are suitable for second crop of pulses. Most of the blocks had medium land condition except Dhenkanal sadar and Kankadahad, where low land condition was high. *Relay* cropping is done particularly in rainfed low lands where excess moisture at the time of rice harvest does not permit tillage operation. However, sequential cropping after harvesting of rice and land preparation is practiced in medium lands (Kushwana and Ali, 1992) [7].

Length of growing period (LGP)

The growing season begins with the onset of monsoon and end of the season happens in between 3-24 December (Table 5) in all blocks except Parajang where there is early withdrawal of soil moisture by 30 November. The duration of growing season for most of the block was 25 weeks (Table 5) in soils having water holding 100 mm/m capacity (Table 4) except Hindol and Parajang where it was 27 and 24 weeks, respectively.

Sowing window of rice

The land preparation is usually done in 21-22 SMW for most of the blocks when the initial probability was $>30\%$. The sowing window of *kharif* rice in Dhenkanal district was found in between 23-24 SMW (Table 6) except Kankadahad, when the conditional probabilities of wet followed by wet (P_{ww}) was $>50\%$ for 20mm threshold limit (Mandal *et al.*, 2015) [8]. Mid duration (120 days) variety like 'Naveen', 'Lalat', 'Konark' and mid late (145 days) duration rice variety like 'Swarna', 'Pratikhya', 'Rani dhan' are harvested between 40-41SMW in medium land and 42-45 SMW in low land respectively. Mid

duration rice are preferred for rice fallow pulse cultivation because it was harvested within 15 October in all blocks then there was vast scope for utilizing the residual soil moisture in the growing season, but in case of long duration rice variety cultivation we should go for *paira* before 10-15 days of harvest of rice (Mazid *et al.*, 1997) [10].

Sowing window of pulses

The sowing window of *rabi* pulses are determined according to the LGP, duration of *kharif* rice and when both the initial and conditional probabilities are >30% (Ray *et al.*, 2018) [14]. In medium land condition, sowing window is in 40 SMW in Kankadahad, 41 SMW in Bhuban, Dhenkanal sadar, Hindol, Kamakhyanagar and Parajang and 42 SMW in Odapada, respectively (Table 7) by zero till method after the harvest of mid duration *kharif* rice (Chand *et al.*, 2011) [3]. In low land condition of Dhenkanal, *rabi* pulses can be sown in between 44-45 SMW in Dhenkanal sadar and in Hindol by zero till method, after mid late duration rice harvest. In between 40-41 SMW in Kankadahad, 41-42 SMW in Bhuban, Dhenkanal sadar and Kamakhyanagar, 42-43 SMW (Table 7) in Gondia, Odapada and Parajang green gram variety like ‘IPM-02-03’, ‘PDM-54’ and black gram variety like ‘PU-31’ are sown with

the residual soil moisture by *paira* method i.e. 15-20 days before the harvest of mid late duration rice. The average weekly rainfall variability was 120-170% and average weekly minimum temperature was 20-23 °C in all blocks, which is optimum for seeding and germination of pulses in that sowing week.

Table1: Mean weekly maximum and minimum temperature (°C) in post- monsoon season

SMW	Tmax	Tmin	Optimum Temperature
40	29.8	23.9	26.85
41	29.7	23.4	26.55
42	29.3	22.7	26
43	28.6	21.4	25
44	28.2	20.4	24.3
45	28.2	19.5	23.85
46	27.7	18.5	23.1
47	27.9	17.9	22.9
48	27.4	16.9	22.15
49	26.9	16.1	21.5
50	26.9	16.3	21.6
51	25.9	15	20.45
52	25.6	14.4	20
District mean	27.8	18.9	23.35

Table 2: Block-wise onset, cessation of monsoon and monsoon rainy days

Blocks	Onset of monsoon	Cessation of monsoon	Monsoon rainy days
Bhuban	17-Jun	9-Oct	115
Dhenkanal sadar	17-Jun	11-Oct	117
Gondia	15-Jun	10-Oct	118
Hindol	14-Jun	13-Oct	122
Kamakhyanagar	17-Jun	10-Oct	116
Kankadahad	14-Jun	10-Oct	119
Odapada	18-Jun	8-Oct	113
Parjang	18-Jun	10-Oct	115

Table 3: Block-wise post-monsoon and winter rainfall

Blocks	Post-monsoon and winter rainfall (mm)
Bhuban	123
Dhenkanal sadar	133
Gondia	118
Hindol	165
Kamakhyanagar	109
Kankadahad	106
Odapada	118
Parjang	99
District mean	121

Table 4: Block wise average evaporation demand (mm/day) and available water holding capacity of soil in post-monsoon and winter season

Blocks	AWHC (mm/m)	Average EVP(mm/day)
Bhuban	100	3.8
Dhenkanal sadar	150	3.8
Gondia	100	3.8
Hindol	100	3.8
Kamakhyanagar	150	3.8
Kankadahad	100	3.8
Odapada	100	3.8
Parjang	100	3.8

Table 5: Block wise duration of growing season (LGP)

Blocks	Start of growing season	End of growing season	LGP (days)	LGP (weekly)
Bhuban	17 June	7 Dec	174	25
Dhenkanal sadar	17 June	24 Dec	191	27
Gondia	15 June	9 Dec	178	25
Hindol	14 June	22 Dec	192	27
Kamakhyanagar	17 June	17 Dec	184	26
Kankadahad	14 June	3 Dec	173	25
Odapada	18 June	6 Dec	172	25
Parjang	18 June	30 Nov	167	24
District mean			179	26

Table 6: Block-wise sowing window of *kharif* rice in Dhenkanal

Blocks	SMW	Month
Bhuban	23	4-10 June
Dhenkanal sadar	23	4-10 June
Gondia	24	11-17 June
Hindol	23	4-10 June
Kamakshyanagar	23	4-10 June
Kankadahad	22	28 May-3 June
Odapada	24	11-17 June
Parjang	24	11-17 June

Table 7: Block-wise sowing window of *rabi* pulses in Dhenkanal

Blocks	Sowing window of pulses			
	Medium land		Low land	
	SMW	Month	SMW	Month
Bhuban	41	8-14 Oct	41-42 (Paira)	11-17 Oct (paira)
Dhenkanal sadar	41	8-14 Oct	44- 45 (zero till method)/ 41- 42 (Paira)	1-7Nov (zero till)/ 11-17 Oct (paira)
Gondia	42	15-21Oct	42-43 (Paira)	18-24 Oct (Paira)
Hindol	41	8-14Oct	44-45 (zero till)	1-7 Nov (Nov)
Kamakshyanagar	41	8-14 Oct	41-42 (Paira)	11-17 Oct (Paira)
Kankadahad	40	1-7 Oct	40-41 (Paira)	4-10 Oct (Paira)
Odapada	42	15-21 Oct	42-43 (Paira)	18-24 Oct (Paira)
Parjang	41	8-14 Oct	42-43 (Paira)	18-24 Oct (Paira)



Fig 1: District map of Dhenkanal

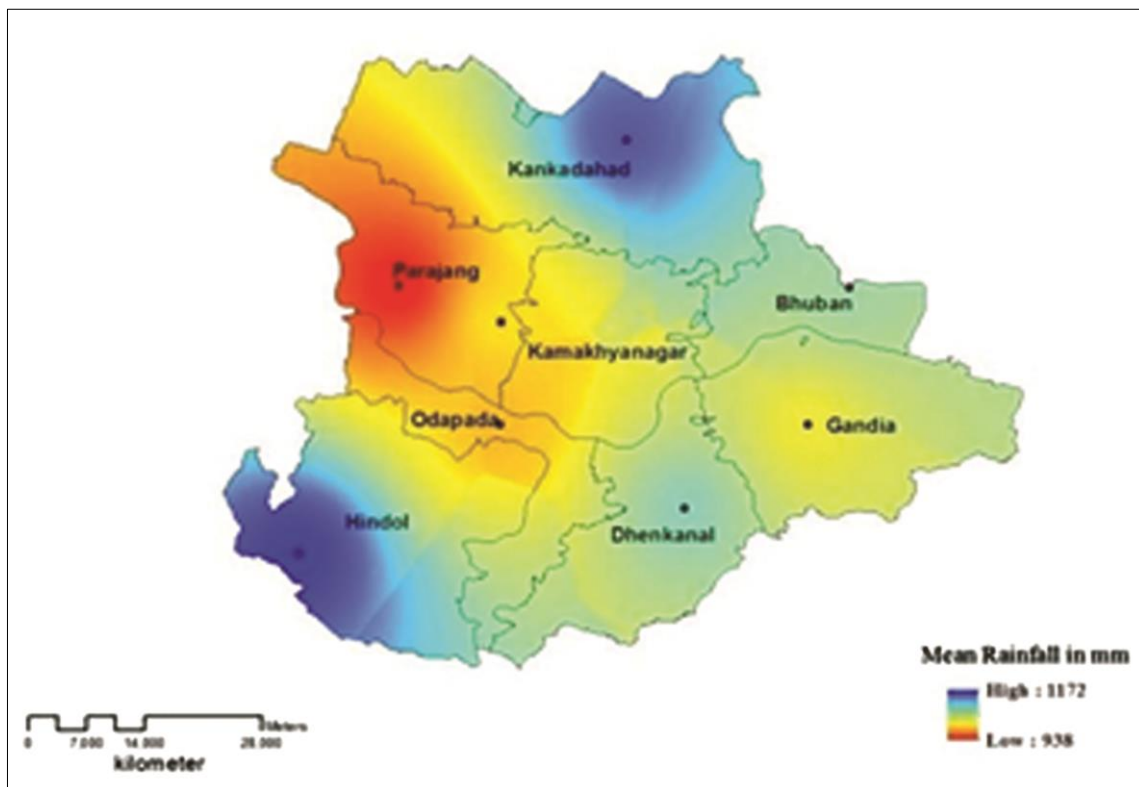


Fig 2: Block-wise mean South-west monsoon rainfall

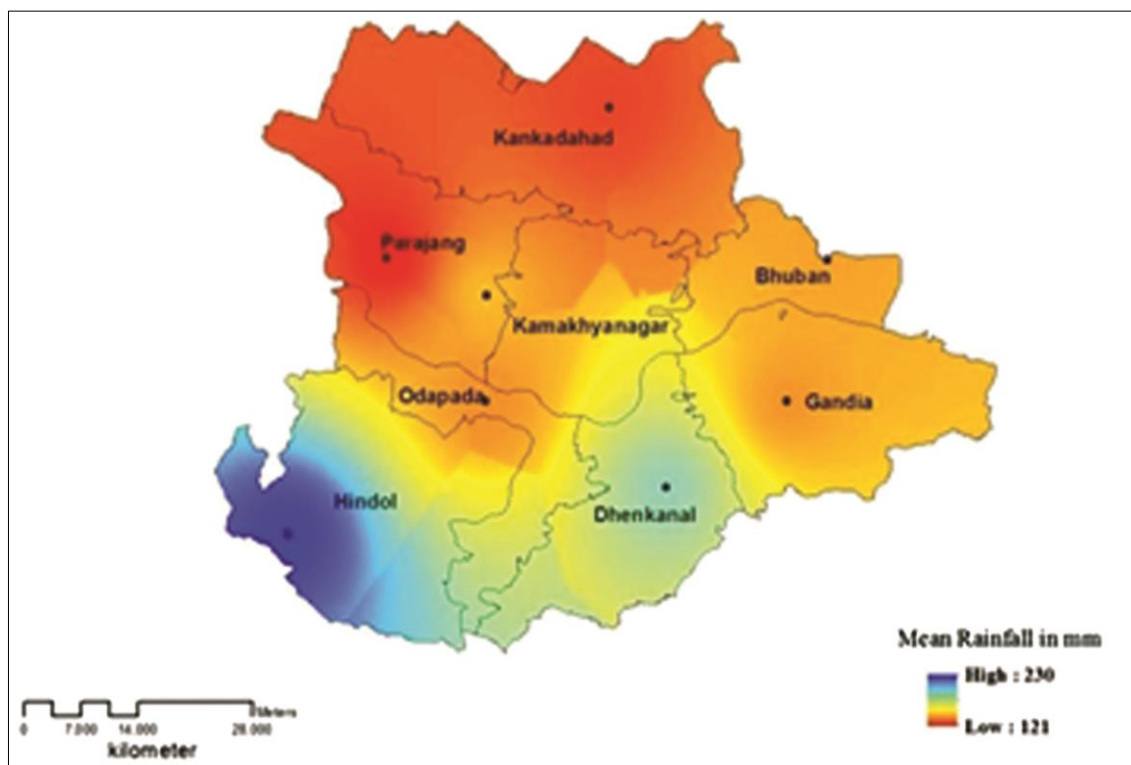


Fig 3: Block-wise mean post- monsoon rainfall

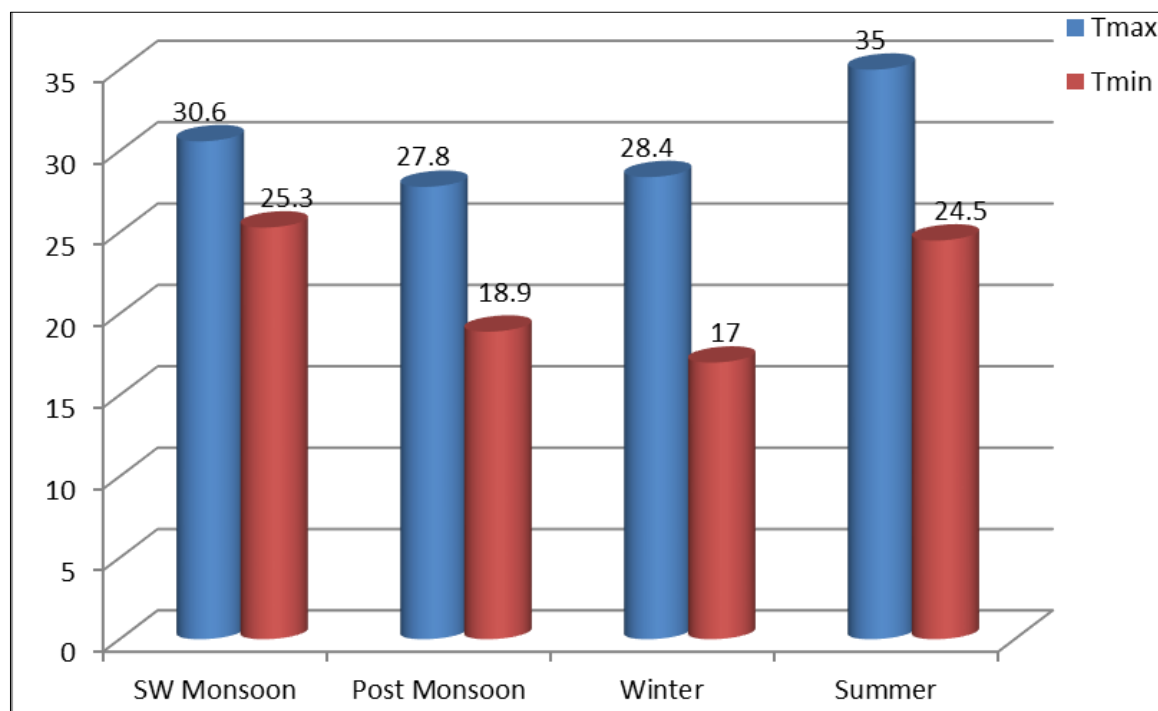


Fig 3: Mean Seasonal temperature

Conclusion

Mid and mid late duration rice which are sown at 23-24 SMW [when the conditional probabilities of wet followed by wet week is $(P_{ww}) > 50\%$], and harvested in between 40-41 SMW in medium land and 42-45 SMW in low land, respectively. This study reveals that there is 115-120 monsoon rainy days, so the farmers can go for short to mid duration *kharif* rice variety for better utilization of residual soil moisture in the fallow land by cultivating short duration (65-70 days) *rabi* pulses. The LGP is 170-180 days for most of the blocks and above 180 days for Dhenkanal sadar, Hindol and Kamakahya nagar. There is maximum scope for utilization of residual soil moisture in those blocks by sowing of pulses in rice-fallow area during 41-42 SMW in medium land by zero till method and 41-43 SMW in low land by *paira* method. However, suitable strategies for adjustment in sowing window of both *kharif* rice and *rabi* pulse crops could be a boon for enhancing the system productivity and profitability of the farming community under challenging rice-fallow condition.

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