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Markov Chain Rainfall Probability Model and Rainy Season Length in Kendrapara District, Odisha for Efficient Crop Management Strategies

OM PRAKASH VERMA[1]*, RANU RANI SETHI[1], ASHOK KUMAR NAYAK[1], NARAYANAN MANIKANDAN[2], SANATAN PRADHAN[1], ANKITA JHA[1], SUSANTA KUMAR JENA[1] and PRASANTA KUMAR PATRA

[1]ICAR – Indian Institute of Water Management, Bhubaneswar, Odisha.
[2]ICAR – Central Research Institute for Dryland Agriculture, Hyderabad, Telangana.

Abstract

Systematic information on rainfall patterns and distribution is essential for crop selection, adopting improved agronomic practices, designing rainwater harvesting structures, and conserving rainwater. This study analyzed the probabilities of rainfall occurrence to know the rainfall onset, withdrawal, and rainy season length for different blocks of Kendrapara district, Odisha. The rainfall analysis showed that the *kharif* season shares 75-78% of annual rainfall with July and August being the wettest. Seasonal rainfall showed a significant increase during *kharif* season while the decreasing trend was observed during the *rabi* and summer seasons. Markov chain analysis showed that the weekly probability for 20-mm rainfall and consecutive two weeks is more than 70% during SMW 25-38. During the June-October period, assured rainfall at 80% probability is greater than 800 mm in four blocks, while in other blocks it ranged between 610-779 mm. Assured rainfall during the *rabi* and summer season is uncertain, however, a 105-126 mm rainfall is received in May in many blocks, useful for summer ploughing and green manure crops. Rainy season length analysis at an 80% probability level revealed that only in 14-16 weeks' rain occurs, thereby, only short-duration paddy can be grown with lower risk. By utilizing October rainfall and conserved soil moisture, short-duration pulses/oilseeds could be grown in all the blocks. However, *kharif* paddy must be sown/transplanted at the optimum time

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CONTACT Om Prakash Verma vermaop@rediffmail.com ICAR – Indian Institute of Water Management, Bhubaneswar, Odisha.

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Introduction

Rainfed agriculture has a prominent role in India's agriculture and economy. Globally, India has the largest cultivable area under rainfed condition to the tune of 71.1 M ha and value of produce out of rainfed ecosystem.[1,2] The study area of the present investigation is the Kendrapara district of Odisha state where more than 70% of farmers are dependent on agriculture and allied activities. Venkateswarlu and Prasad[3] opined that the rainfed agro-ecosystem plays key role in Indian agriculture with an enormous type of crops, cropping systems, and agro-forestry. However, inter-annual variability of the Indian summer monsoon due to the prevalence of El Nino/ENSO activities also brink a high risk to rainfed agriculture and it was found that a negative correlation exists between sea surface temperature anomaly and southwest monsoon rainfall over Odisha state.[4] Rainfall is highly variable weather element both spatially and temporarily and Panda *et. al.,*[5] reported that any variation in rainfall directly affects the livelihood of the farming community of Kendrapara district where 94% population lives in rural areas. Farm output would get affected owing to dry spell in critical crop growth stages during good rainfall years too. Hence, systematic information on rainfall patterns, their variability and probability paves the way for crop selection, adoption of better agronomic practices, and designing of different rainwater storage structures[6,7,8,9,10,11,12] and conservation of excess rainwater in storage structures to utilize during dry spells.[13,14] For instance, the characterization of rainfall like weekly, monthly, inter- and intra-seasonal distribution of rainfall, the dates of onset, cessation, and rainy season length is very important for reaping a good harvest in the challenged rainfed agro-ecosystem.[15] Most importantly monsoon onset dates of crop growing season enable the farmers to take better crop management decisions.[15,16,17,18] Many researchers have characterized the rainfall through probability, trend, heavy rainfall events and length of rainy season analysis for different districts of Odisha state.[19,20] However, studies on weekly rainfall probability and the start of rainy season and planning a cropping pattern at the block level for the district of Kendrapara is limited. Hence, in order to fulfill this gap, the present investigation was conducted to determine better crop planning for different blocks of Kendrapara, Odisha using weekly, monthly and seasonal rainfall probability analysis and also by working out start, end and duration of rainy season.

Material and Methods

Description of the Study Site

The Kendrapara district is located in the central coastal plain and hills agro-climatic zone of Odisha with a total geographical area of 2640 km^2. The district spreads between 22º 21' N to 20º 47' N latitude and 86 º 15 'E to 87 º 03' E longitudes on the eastern coast of Odisha. The district is endowed with water resources due to the rivers *viz*, the Mahanadi, the Brahmani, the Baitarani, the Kharasrota, the Luna, and the Karandia. In addition to these major rivers, around 19 small rivers (locally known as *nallas, joras* or *gullias*) also flow through the nine blocks of the district, and floods are quite common during monsoon season due to high-intensity rainfall, saucer shape topography, and tidal ingression. The nine blocks of the Kendrapara district are shown in Fig.1. Rice is the main crop during the *kharif* season while pulse and oilseed crops are cultivated during the *rabi* and summer seasons with residual soil moisture or supplemental irrigation. As per the District Irrigation Plan of Kendrapara, Kendrapara and Pattamundai blocks are having 100% irrigation facilities followed by De*rabi*s (92%), Marshaghai (85%), and Aul (72%) during the *kharif* season.[21] The least area under irrigation is noticed in the Rajnagar block (20%) followed by Mahakalpara (25%) and Rajkanika (35%).

Rainfall Data

To carry out rainfall analysis, daily rainfall data of all nine blocks of Kendrapara district for 26 years (1994 - 2019) were collected from the website of Odisha Rainfall Monitoring Mission (https://rainfall.nic.in/login.asp). Daily rainfall data has been converted to weekly, monthly, seasonal [*Kharif* (June-Oct), *Rabi* (Nov-Feb), Summer (Mar-May)] and annual basis. The methodology followed in this study is presented in the flow chart (Fig. 2). MAKESENS (Microsoft-EXCEL template) was employed for computing Mann-Kendall test.[22]

Fig.1: Study area - Kendrapara district of Odisha state

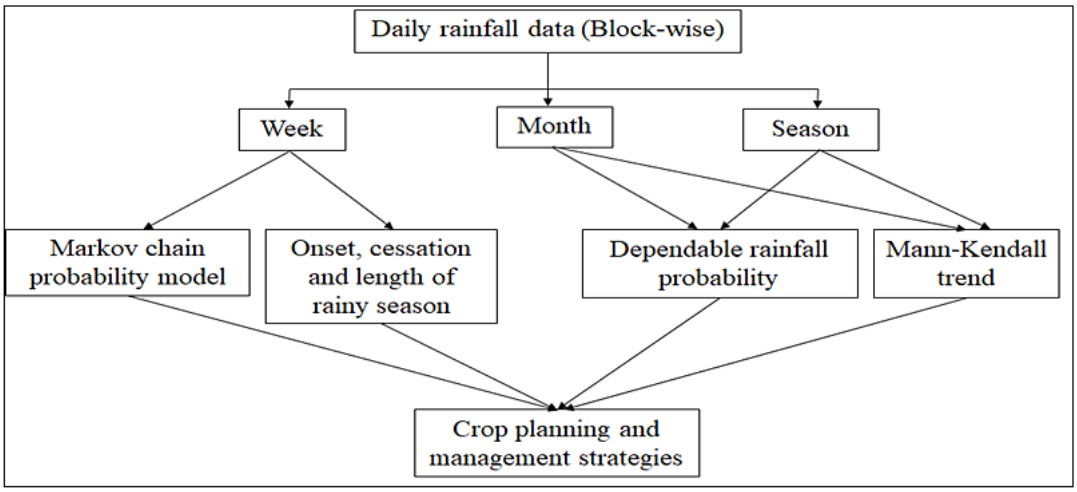

Fig. 2: Flow chart of methodology used for the study

Initial and Conditional Probability

Wet and dry weeks probability was computed based on Markov chain probability procedure.[23] In present study, wet week was referred as a week which received ≥ 20 mm rainfall and if the weekly rainfall ≤20 mm it was considered as a dry week. Following formula (Eqns 1& 2) was used to find out the probability for a wet week.

$$P(W) = F(W)/N \quad ...(1)$$

where, P (W) = Initial probability of the week being wet, F (W) = frequency of wet weeks and N = total number of years considered for analysis.

$$P\ w/w = F(w/w)/\ F(W) \quad ...(2)$$

where, Pw/w =conditional probability of a wet week preceded by a wet week,

F (W/W) = frequency of wet week preceded by a wet week, F (W)=frequency of wet weeks

Dependable Rainfall Probability

Weibull's formula was employed (Eq 3) to work out dependable rainfall at different probability level.

$$P=m\backslash n+1 \times 100 \quad ...(3)$$

where P is % probability, m = rank number and N = number of years of data used.

Monthly and seasonal rainfall of each year was arranged in ascending order, assigned with a rank and then percent probability (P) was estimated. In the present study, monthly and seasonal (*Kharif, Rabi* and Summer) rainfall probability at 20, 50 and, 80% were worked out and it is referred to as high, medium, and low risk. Bhakar *et. al.,*[24] reported that rainfall at 80% probability can be safely considered as dependable rainfall while, likelihood rainfall at 50% probability level is the highest for taking any risk, respectively.

Computing the Start, End and Duration of the Rainy Season

As per the procedure proposed by Kothari *et al.,*[25] weekly rainfall data was utilized to find out the onset, cessation and duration of rainy season. Weekly rainfall up to 75 mm was added by forwarding accumulation (20+21+…+ 52 week). Starting week of rainy season was identified whenever a week receives 75 mm rainfall because this much rainfall amount is needed for land preparation and sowing of crops.[25,26] The soil must have reached its wilting point due to the prevalence of prolonged dry spells in the hot summer season. Land preparation and rainfed crops sowing would be easy once a week receives 75 mm rainfall and hence previous researchers have chosen this onset criterion. Mandal *et. al.,*[27] also used weekly rainfall of 75 mm to find out starting week for sowing if rainfed rice in Sagar Island of West Bengal. Backward accumulation of 20 mm rainfall in a week (52+51+50+…..+35 week) was considered to find out the withdrawal of rainy season. For monsoon withdrawal, 20 mm of accumulated rain was deemed necessary, which is enough to prepare fields for the post-rice crops.[28] Rainy season length was found by subtracting the week during which the season ends from the week during which the season starts. Additionally, the rainy season onset week, end week, and length in weeks were estimated at different probability levels.

Table 1: Average monthly rainfall and its trend in different blocks of the Kendrapara district, Odisha (1994-2019)

Month	Aul	Derabis	Garadapur	Kendra	Mahakalpara	Marshpara	Pattaghai	Rajkanikamundai	Rajnagar
January	32 (2) D**	38 (2) D**	24 (2) D**	29 (2) D**	25 (2)	24 (2) D*	27 (2)	27 (2) D*	20 (1) D*
February	34 (2) D**	31 (2) D***	33 (2) D***	29 (2) D***	27 (2) D**	32 (2) D***	24 (2) D**	36 (2) D**	21 (1) D**
March	50 (3)	50 (3) D*	38 (3) D*	45 (3)	41 (3)	37 (2)	41 (3)	48 (3)	39 (3)
April	45 (3)	50 (3)	31 (2)	63 (4)	36 (3)	38 (3)	38 (3)	37 (3)	40 (3)
May	124 (8)	126 (8)	105 (8)	128 (8)	112 (8)	113 (7)	120 (8)	110 (8)	124 (8)
June	214(14)	195 (12)	156 (11)	191 (12)	170 (12)	184 (12)	186 (13)	212 (15)	193 (13)
July	264 (17)	286 (18)	219 (16)	315 (20)	284 (20) I*	280 (19) I*	281 (19) I*	277 (19) I**	292 (19)
August	270 (18)	271 (17) I**	267 (19)	283 (18)	249 (17) I*	281 (19) I**	257 (18)	234 (16)	260 (17)
September	232 (15) I***	254 (16) I*	251 (18)	251 (16)	216 (15) I***	246 (16)	240 (16) I**	217 (15) I**	250 (16) I*
October	183 (12)	182 (12)	186 (13)	182 (11)	176 (12)	185 (12)	179 (12)	166 (12)	201 (13)
November	51 (3)	58 (4)	46 (3)	51 (3)	59 (4)	58 (4)	40 (3)	50 (3)	60 (4)
December	24 (2)	33 (2) D**	35 (3) D***		28 (2) D***		28 (2) D**	28 (2) D***	29 (2) D**
27 (2) D***	33 (2) D**								

Values in parenthesis refer to the percentage contribution of rainfall of each month to annual rainfall; D-Decreasing trend; I-Increasing trend; *, ** and *** refers to 10, 5 and 1 % significantlevel, respectively

Results and Discussion

Variability of Rainfall in Different Blocks

Average monthly rainfall in different blocks indicated that July and August were the wettest months of the year. These two months are contributing 16-20 percent of annual rainfall individually followed by September (15-18%), June (11-15%), and October (11-13%). It was noticed that in the Garadapur block, 18 percent of annual total rainfall was received in September month which was higher than in July (16%). In the remaining months, a low amount of rainfall in the range of 20-60 mm was experienced across the blocks except in May (Table 1).

Significant rainfall amount of 105 mm (Garadapur block) to 126 mm (De*rabi*s block) was received during May owing to convection activity or a low-pressure system in the Bay of Bengal. This rainfall can be efficiently utilized for summer ploughing and to raise green manure crops to improve the soil's physical, chemical and biological properties. Rautaray *et. al.*[29] found that mid-May to mid-June is optimum for sowing *Sesbania green manure* crop before growing the lowland rice crop and it would help the farmers to reduce inorganic fertilizer and to counter soil health deterioration and environmental degradation over eastern parts of India. *Kharif* is a major crop growing season, which receives 75-78% of annual rainfall (AR). The highest amount of rainfall was observed in the Kendrapara block (1221 mm) followed by the Rajnagar block (1196mm) and the lowest in Garadapur (1080 mm) and Mahakalpara (1095 mm) blocks. *Rabi* season is the driest season of the year which receives 8-10% of annual rainfall while it was 12-15% for the summer season.

Monthly and Seasonal Rainfall Trend

Mann-Kendall trend test revealed that no significant trend was observed in any of the blocks of Kendrapara district during April, May, June, October and November (Table 1). However, a significant increasing trend was noticed during July-September months and significant declining trend was seen during December-March months in many blocks of Kendrapara district.

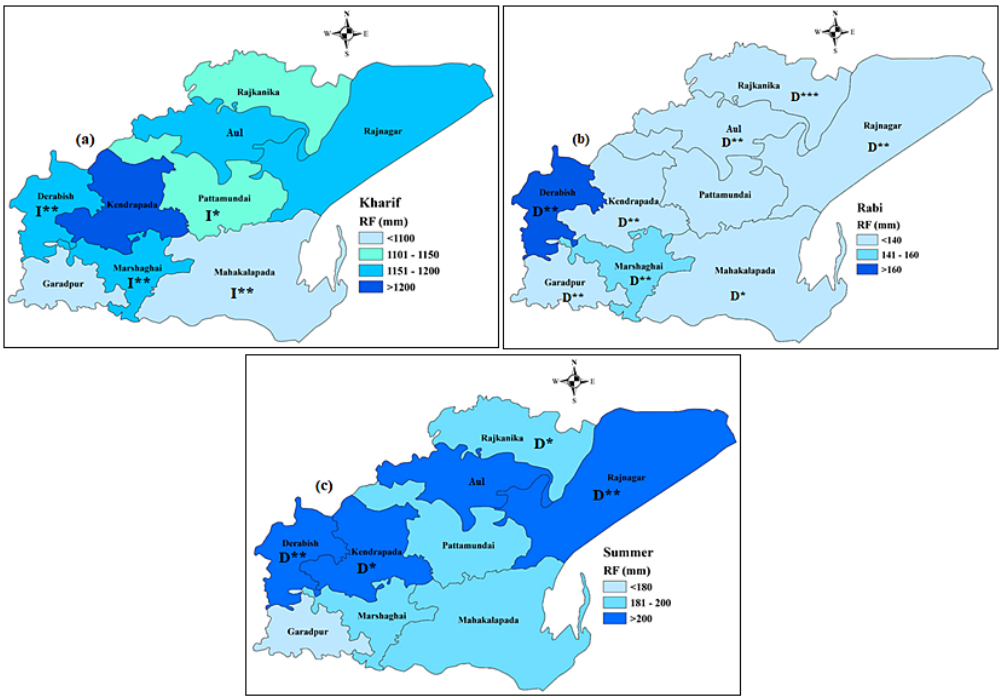

Fig. 3: Average (a) kharif(b) rabi and (c) summer seasonal rainfall and its trend in different blocks of Kendrapara district *(D-Decreasing trend; I-Increasing trend; * and ** Significant at p<0.05 and p<0.01 level, respectively)*

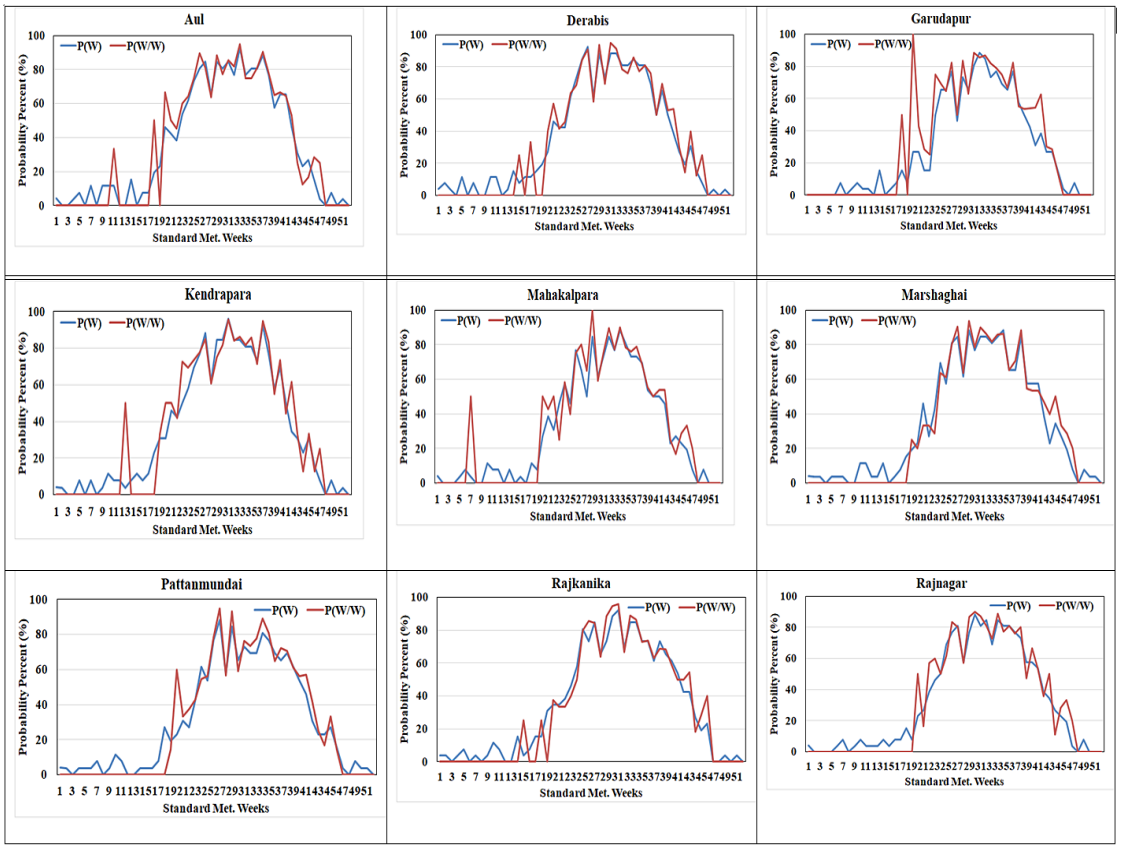

Fig. 4: Initial and conditional probability for 20 mm in a week in different blocks of the Kendrapara district

Seasonal rainfall trend indicated that all blocks of the district showed significant decreasing trend except Pattamundai during *rabi* season. During summer season too, significant decreasing trend in rainfall was noticed in De*rabi*s, Kendrapara, Rajnagar and Rajkanika blocks. At the same time, four out of nine blocks like De*rabi*s, Mahakalpara, Marshaghai and Pattamundai showed significant increasing trend during *kharif* season (Fig.3). Increasing tendency in rainfall during *kharif* season months gives an opportunity to harvest and store excess rainwater in storage structures and can be effectively utilized during dry period/months as *rabi* season showed significant decreasing rainfall trend.

Initial and Conditional Probability of Weekly Rainfall

Percentage probability for receiving ≥ 20 mm rainfall in a week and two weeks in a row for all the nine blocks of the Kendrapara district is furnished in Fig. 4. In general, the chance was very low from 1st Standard Meteorological Week (SMW) and slowly it picked up to 50% during SMW 20-23 owing to the occurrence of convective rainfall/ low pressure-induced pre-monsoon rainfall. Hence, sowing operation may be started during these weeks and it would help in better germination and establishment because the weekly rainfall probability for ≥ 20 mm was between 50 and 70% from 24 to 25 SMW. After the onset of the monsoon, the probability - for a wet week and two wet weeks consecutively rose to 70% from SMW 25 to SMW 38 in different blocks of the district. During these weeks, excess rainwater through runoff can be stored in farm ponds and utilized for supplemental irrigation during dry spells. Again, the wet week probability dropped 50% from SMW 41 onwards due to the cessation of the southwest monsoon and reached 0% at the end of the year.

Table 2: Dependable rainfall (mm) during different seasons at different probabilities in different blocks of the Kendrapara district

Name of the block	*Kharif*			*Rabi*			Summer		
	20%	50%	80%	20%	50%	80%	20%	50%	80%
Aul	1528	1036	777	265	92	42	369	174	130
Derabis	1643	1145	807	297	158	50	354	197	93
Garadapur	1610	961	631	189	98	24	265	162	53
Kendrapara	1555	1201	924	206	137	40	368	222	121
Mahakalpara	1410	1153	639	208	135	42	292	194	75
Marshaghai	1575	1156	846	281	116	31	309	172	86
Pattamundai	1628	1050	610	214	104	53	352	150	77
Rajkanika	1470	1080	779	243	97	36	269	189	97
Rajnagar	1524	1147	848	217	133	31	311	169	110

Dependable rainfall at various probability levels for different blocks is presented in the table 2. *Kharif* seasonal rainfall at 20% probability indicates that all blocks of the district receive more than 1400 mm rainfall which is more than sufficient to grow even long-duration paddy crops. However, this amount of rainfall may be expected for only 2 out of 10 years only and hence, there exist a high risk. Rainfall at a 50% probability level was above 1000 mm in all blocks of the Kendrapara district except Garadapur (961 mm). Assured rainfall at an 80 percent level is considered optimum for agricultural crop planning. Gupta *et. al.,*[30] also recommended rainfall at 80% probability level to find cropping systems for rainy and winter season over Doon Valley. At this probability level, 924 mm of rainfall can be expected during the *kharif* season only in the Kendrapara block. The lowest rainfall was observed in Pattamundai (610 mm) followed by the Garadapur (631 mm) and Mahakalpara (639 mm) blocks. In other blocks, seasonal rainfall varied from 777 mm to 848 mm at an 80% probability level. Assured rainfall amount at an 80% probability level indicates that rainfed rice cultivation with a short duration variety can be done in four blocks *viz.*, Kendrapara, Rajnagar, Marshaghai, and De *rabi*s as the rainfall amount is above 800 mm. In other blocks, it ranged from 610 mm to 779 mm which shows that rainfed rice cultivation is risky unless an additional water source for irrigation is available. Probable rainfall at an 80% level in different blocks during the *rabi* and summer seasons was very less and farmers cannot depend on rainfall for meeting the water requirement of the crops. It clearly shows that in the Kendrapara district, though all the blocks receive around 1000 mm of rainfall at a 50% probability during *kharif* season and farmers can cultivate rice under rainfed situations without risk if they could store excess rainwater in water harvesting structures for providing life-saving irrigation during dry spell period within the crop growing season. In addition, stored water would also allow them to take up a short-duration pulse/ oilseed crop during *rabi* season. Sethi *et. al.,*[14] found that 69% of annual runoff is occurring during the June-September period in the Kendrapara district and suggested conserving this runoff water in rainwater storage structures and this stored water can be utilized during dry spells within *kharif* season as well as in the *rabi* and summer seasons

The onset of the rainy season was observed on 23/24 Standard Meteorological Week (SMW), 24/25 SMW, and 26/27 SMW at,20,50 and 80 percent probability levels, respectively over different blocks of the Kendrapara district. The rainy season was ending during 39 SMW in Mahakalpara and Pattamundai blocks, during 41 SMW in De*rabi*s block and 40 SMW in other blocks at an 80 percent probability level. At the same time, a 50 percent probability end of the rainy season was noticed during 43/44 SMW and at 20 percent probability, it was 46 SMW in all blocks of the district. It is inferred from the duration of the rainy season that the rainy season extends up to 23/24 weeks (161-168 days) at a 20 percent probability. It is expected that 19/20 weeks

(133-140 days) of the rainy season in alternate years (50% probability) over different blocks of the district. The lowest duration of the rainy season was noticed at a high probability level (80%) and it was 14-15 weeks (98-105 days) in all blocks except in De*rabi*s where the rainy season duration was one week higher than the remaining blocks (16 weeks - 112 days). The analysis suggests that under rainfed conditions, long-duration paddy (150 days) can be cultivated at high risk; medium-duration paddy (125-135 days) at medium risk while short-duration paddy (90-105 days) is at lower risk in Kendrapara district.

Table 3: Probabilities of initiation, end, and duration of the rainy season in different blocks of the Kendrapara district

Name of the block	Onset week			Withdrawal week			Duration of rainy season in weeks		
	20%	50%	80%	20%	50%	80%	20%	50%	80%
Aul	23	24	26	46	43	40	24	20	15
Derabis	23	24	26	46	44	41	24	21	16
Garadapur	24	25	27	46	44	40	23	20	14
Kendrapara	23	25	26	46	44	40	24	20	15
Mahakalpara	24	25	26	46	43	39	23	19	14
Marshaghai	24	25	27	46	44	40	23	20	14
Pattamundai	23	25	26	46	43	39	24	19	14
Rajkanika	23	24	26	46	43	40	24	19	15
Rajnagar	23	25	26	46	43	40	24	19	15

Table 4: Change in area (ha) under major crops between 2001-2010 and 2011-2019 in Kendrapara district

Crop	Period	*Kharif*	*Rabi*
Paddy	2000-2010	132475	4100
	2011-2019	127902	1419
	Difference	-4573	-2681
Total pulses	2000-2010	325	64844
	2011-2019	31	78346
	Difference	-321	13502
Total oilseeds	2000-2010	0	13483
	2011-2019	3	10684
	Difference	3	-2799
Other crops (other cereals, total vegetables, fruits, spices, fibers and Sugarcane)	2000-2010	17309	17162
	2011-2019	24267	22297
	Difference	6958	5136

Source: Odisha Agriculture Statistics, Dept. of Agriculture & Farmer's Empowerment, Govt. of Odisha

Change in the Area Under Major Crops in Kendrapara District from 2000-2010 to 2011-2019

In general, two main cropping seasons are practiced in the Kendrapara district with rice as the main crop during the *Kharif* season and rice/ pulse/ oilseed crops during the *Rabi* season. As per the IRRI[31] report, there is a decline in crop diversification in Odisha; and 80, 10 and 10 % of the cropped area is covered by rice, pulses and other food crops, respectively by 2014-15. Crop area statistics (Odisha Agriculture Statistics, Dept. of Agri. & Farmer's Empowerment, Govt. of Odisha) of Kendrapara district indicated that rice acreage reduced by 4573 and 2681 ha during *kharif* and *rabi* seasons, respectively during 2010 and 2019 (Table 4). At the same time, there is upsurge in area (+13502 ha) under pulse during the *rabi* season and decline in area (-321 ha) under pulse during *kharif* season. The cropped area under *rabi* oilseed crops also decreased by 2799 ha in recent period (2011-2019) when compared to 2000-2010. The schemes launched by the Government of Odisha like Targeting Rice Fallows in Eastern India[31] and multipronged strategies of Odisha University of Agriculture and Technology in collaboration with line departments to improve the pulse research and extension in Odisha state could be the reasons for the rise in *rabi* pulse acreage in recent years.

Crop Planning and Management Strategies

The present analysis indicated that under rainfed conditions, direct sowing/nursery sowing of paddy crop may be taken in SMW 24 (June 11-17) for a short duration drought tolerant paddy (90-120 days) like Kamesh and Satyabhama, especially in Rajnagar, Mahakalpara and Rajkanika blocks as these blocks have the least area (20-35%) under canal irrigation. This would help in the effective utilization of the rainwater during the entire *kharif* season and the critical phases of the crop like panicle development, flowering, and grain development fall during August and September. Under delayed sowing conditions, farmers have to go for direct sowing by SMW 26 (June 25-July 1) with extra short-duration (90-100 days) varieties (Shabhagidhan and Vandhana) to harvest the crop at the cessation of the southwest monsoon. The district is prone to both floods as it is in the vicinity of the Bay of Bengal and drought due to the vagaries of the monsoon. To cope with this situation, farmers should have a plan for water harvesting structures to drain and conserve the excess rain/flood waters during the flood as well as the cultivation of drought-tolerant varieties.

Blocks like Kendrapara, Pattamundai, De*rabi*s, Marshaghai and Aul had more than 70% net sown area under irrigation, medium (Satabdi, Rajalakshmi, Ajay, Satyakrishna, improved Lalat) and long-duration (Pooja, Reeta, CR Dhan 300, CR Dhan 701) cultivars of paddy can be grown. In this case, also, it is optimal to go for sowing by SMW 24/transplanting by SMW 28 which would facilitate the farmers to fully utilize the rainwater up to September/October, and thereafter irrigation requirements can be met from canal water. Das[32] clearly stated that sowing upland rice and rice transplanting under irrigated conditions beyond SMW 29 (July 16-22) affect productivity badly even with proper crop management practices. Further, he reported that paddy is transplanted three to four times and continues even in September month due to recurrent floods in this part of the state which led to the poor yield of 0.5-1.0 t/ha. Subash *et. al.,*[33] also opined that rice productivity would reduce by 50%, if it is planted beyond August in the Bihar state. Varieties like Swarna Sub-1, Reeta, Sarala, and Durga are suggested for the blocks where shallow low land/semi-deep water-logged ecosystem is existing as well as against to withstand water stagnated conditions for week/two weeks.

Rainfall analysis showed that ample opportunities exist to cultivate pulse/ oilseed crops after *kharif* season paddy as around 37,000 ha of land are under rice fallow in Kendrapara district.[34] Sowing/ transplanting of *kharif* paddy in time and cultivation of short/extra short-duration cultivars is one of the strategies for the successful cultivation of *rabi* pulse crops, especially in Rajnagar, Mahakalpara, and Rajkanika blocks. Short-duration pulse crops (60-80 days) like green gram (OUM11-5, OBGG 52, IPM 02-3) and black gram (Prasad, Ujala, and PU 31) can be taken up[34] utilizing the stored soil water after the cessation of the southwest monsoon as well as rain in October to harvest the good crop and to enhance the farm income. It is highly possible to cultivate *rabi* pulse and oilseed crops like groundnut in other blocks of the district looking into the available irrigation sources. The potential use of groundwater in all the blocks is another option as the stage

of overall ground water development of the district is only 53% and their status is safe in all the blocks.[35] However, conjunctive use of canal and groundwater can be utilized wherever saline water issue is noticed. Above all, ensuring the crops under *Pradhan Mantri Fasal Bima Yojana* is a conscious option to safeguard in the event of crop failure due to flood/ drought or any other natural disasters.

Conclusions

The rainfall analysis (month, season and annual scale) for the different blocks of Kendrapara district indicated that July and August are the wettest months and contribute 16-20% of annual rainfall while, *kharif* season rainfall shares about 75-78%. Among the blocks, Kendrapara and Garadapur receive the highest and lowest rainfall during the *kharif* season. Markov Chain initial and conditional probability analysis showed that the probability for 20 mm rainfall in a week and consecutive two weeks also is more than 70% during SMW 25-38. Assured rainfall at an 80% probability is more than 800 mm during the June-October period in Kendrapara, Rajnagar, Marshaghai, and Derabis blocks while in other blocks it ranged between 610 mm and 779 mm only. Mann-Kendall trend test indicated a significant increasing trend in the *kharif* season while a significant decreasing trend was observed during *rabi* and summer seasons. Hence, it is highly possible to store runoff water in water harvesting structures during excess rainfall period to arrest flooding water and utilize it during recurrent dry spells during the cropping season and also for life-saving irrigation for *Rabi* crops. Though, assured rainfall during the *rabi* and summer seasons was very uncertain, a significant amount of rainfall (105-126 mm) is being received in May in different blocks which could be used for summer ploughing and growing green manure crops like Sesbania sp. Length of the rainy season analysis revealed that at an 80% probability level it was 14-16 weeks only and it is understood that under rainfed conditions, long-duration paddy (150 days) can be cultivated at high risk; medium duration paddy (125-135 days) at medium risk while short-duration paddy (90-105 days) is at lower risk. Short-duration paddy (90-120 days) can be sown by SMW 24 in Rajnagar, Mahakalpara, and Rajkanika blocks as these blocks had the lowest irrigation sources. This would help for efficient utilization of available rainwater during the *kharif* season and protect the crop after the cessation of rainy season from the soil moisture stress. In other blocks, where other irrigation sources are available, medium and long-duration paddy sowing and transplanting activity are to be completed by SMW24 and SMW 28 to avoid yield loss due to delayed planting. Cultivation of short-duration pulses like green gram, black gram, and oilseeds like groundnut in all the blocks of Kendrapara district is possible by utilizing rainfall during October and conserved soil moisture. However, *kharif* season paddy must be sown/ transplanted at an optimal time to reap a good harvest.

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Conflict of Interests

All contributing authors declare no conflict of interest.

References

1. Rao CS, Lal R, Prasad JVNS, Gopinath KA, Singh R. Jakkula VS, Sahrawat KL, Venkateswarlu B, Sikka AK, Virmani SM. Potential and challenges of rainfed farming in India. In: *Advances in agronomy*. (Ed. Sparks, D.L.), 2015; 133: 115-181.
2. NRAA. Prioritization of Districts for Development *Planning in India: A Composite Index Approach.* National Rainfed Area Authority, New Delhi, 2020; 128p.
3. Venkateswarlu B, Prasad JVNS. Carrying capacity of Indian agriculture: Issues related to rainfed agriculture. *Current Sci.,* 2012; 102 (6): 882-888.

4. Manikandan N, Kar G, Roy Chowdhury S. Impact of El-Niño Event on Seasonal and Annual Rainfall over Odisha State. *J. Indian Soc. Coastal Agric. Res*., 2017; 35 (2): 48-52.
5. Panda T, Mishra N, Mohanty RB. Diversity of some threatened indigenous rice varieties cultivated in Odisha, *India. Environment and Natural Resources J.* 2013; 11 (2):41-57.
6. Jena SK, Sahoo N, Roy Chowdhury S, Mohanty RK, Kundu DK, Mohanty M. Optimizing Micro water resources design and integrated farming system approach for enhancing productivity of waterlogged area. *J. Indian Soc. Coastal Agric. Res.,* 2006; 24 (1): 180-183.
7. Sethi RR, Kumar A. Rainfall characteristics and planning for design of storage structures. *J. Indian Water Works Association,* 2008; 40 (2): 103-110.
8. Patil DU, Nandgude SB, Mahale Dillip, Jena SK, Kumar A. Mitigation of critical dry spells for higher yield in Kharland region of Maharashtra. *J. Indian Water Resources Soc.,* 2009; 29 (4): 22-29p.
9. Sreedhara S, Gopakkali P, Nandini R. Rainfall probability analysis for crop planning in Shivamogga taluka of Karnataka. *J. Agrometerol.,* 2016; 18(1): 168-170.
10. Sattar A, Khan SA, Banerjee S. Assured rainfall analysis for enhanced crop production under rainfed condition in Bihar. *J. Agrometerol.,* 2018; 20 (4): 332-335.
11. Prabhakar AK, Singh KK, Lohani AK, Chandniha SK. Assessment of regional level long term gridded rainfall variability over the Odisha State of India. App. *Wat. Sci.,* 2019; 9:93
12. Ganchaudhuri S, Sarmah K, Roy L, Goswami J. Rainfall probability analysis for crop planning of Unakoti and West Tripura district of Tripura, India. *Int. J. Environ. Clim. Change.* 2022; 12 (11): 2520-2529.
13. Kar G. Rainfall probability analysis for sustainable production strategies in coastal Orissa. *J. Agrometerol.*, 2002; 4(2): 181-185.
14. Sethi RR, Srivastava RC, Behara A, Das M, Brahmanand PS, Tripathy JK. Runoff estimation and water management options for coastal Odisha. *Indian J. Ecol.,* 2017; 44(3): 451-455.
15. Bal SK, Manikandan N, Sandeep VM, Vijaya Kumar P, Lunagaria MM, Subba Rao AVM, Pramod VP, Singh VK. Criteria based decisions for determining agroclimatic onset of the crop growing season. *Agric. For. Meteorol.,* 2022; 317: 108903.
16. Raes D, Sithole A, Makarau A, Milford J. Evaluation of first planting dates recommended by criteria currently used in Zimbabwe. *Agric. For. Meteorol.*, 2004; 125: 177-185.
17. Marteau R, Moron V, Philippon N. Spatial coherence of monsoon onset over western and central Sahel (1950-2000). *J. Clim.*, 2009; 22: 1313-1324.
18. Huggi L, Shivaramu HS, Manjunataha MS, Soumya DV, Vijayakumar P, Lunagaria MM. Agro-climatic onset of cropping season: A tool for determining optimum date of sowing in dry zones of southern Karnataka. *J. Agrometeorol.*, 2020; 22 (3): 240-249.
19. Swain M, Pattanayak S, Mohanty UC. Characteristics of occurrence of heavy rainfall events over Odisha during summer monsoon season. *Dynam. Atmos. Oceans,* 2018; 28:107-118.
20. Nageswararao MM, Sinha P, Mohanty UC, Panda RK, Dash GP. Evaluation of district level rainfall characteristics over Odisha using high resolution gridded dataset (1901–2013). *SN App. Sci.* 2019; 1:1211
21. Anonymous. *Districtirrigation plan of Kendrapara (Odisha).* District level implementation committee, Kendrapara, Odisha, 2016; 180p.
22. Salmi T, Maatta A, Anttila P, Airola TR, Amnell T. Detecting trends of annual values of atmospheric pollutants by the Mann-Kendal test and Sen's slope estimates-the Excel template application MAKESENS. User manual, Finish Meteorological Institute, 2002; 35p.
23. Tettey M, Oduro FT, Adedia D, Abaye DA. Markov chain analysis of the rainfall patterns of five geographical locations in the south eastern coast of Ghana. *Earth Perspectives,* 2017; 4:6.
24. Bhakar SR, Mohammed I, Devanda M, Chhajed NC, Bansal AK. Probability analysis of rainfall at Kota. *Indian J. Agric. Res.*, 2008;

42 (3): 201-206.

25. Kothari AK, Jain PM, Kumar V. Analysis of weekly rainfall data using onset of monsoon approach for micro level crop planning. Indian *J. Soil Cons.*, 2009; 37 (3):164-171.
26. Panigrahi B, Panda SN. Dry spell probability by Markov chain model and its application to crop planning in Kharagpur. *Indian J. Soil Conserv.,* 2002; 30 (1):95-100
27. Mandal S, Choudhury BU, Satapathy LN. Monsoon variability, crop water requirement, and crop planning for kharif rice in Sagar Island, India. *Int. J. Biometeorol.*, 2015; 59:1891-1903.
28. Reddy GVS, Bhaskar SR, Purohit RC, Chittora AK. Markov chain model probability of dry, wet weeks and statistical analysis of weekly rainfall for agricultural planning at Bangalore. Karnataka *J. Agric. Sci*., 2008; 21:12-16.
29. Rautaray SK, Pradhan S, Mohanty S, Dubey R, Raychaudhuri S, Mohanty RK, Mishra A, Ambast SK. Energy efficiency, productivity and profitability of rice farming using Sesbania as green manure-cum-cover crop. *Nutr. Cycl. Agroecosys.*, 2019; 116 (1): 83-101.
30. Gupta SK, Babu Ram, Tejwani KG. Weekly rainfall of India for planning cropping programme. *Soil Conserv. Digest,* 1975; 3 (1): 31-36.
31. IRRI. Annual Progress Report: Increasing productivity of rice-based systemsand farmers' income in Odisha. International *Rice Research Institute,* New Delhi, 2019; 173p.
32. Das SR. *Rice in Odisha.* IRRI Technical Bulletin No. 16. Los Baños (Philippines). International Rice Research Institute, 2012; 31p.
33. Subash N, Sikka AK, Haris AA. Markov chain approach-dry spell and wet spell rainfall probabilities for rice-wheat planning. Indian *J. Soil Conserv.*, 2009; 37 (2): 91-99.
34. OUAT. *OUAT strategies for pulse production in rice fallows of Odisha.* Odisha University of Agriculture and Technology, Bhubaneswar, 2016; 37p.
35. CGWB. *Ground Water Information Booklet of Kendrapara district, Orissa.* Central Ground Water Board, Ministry of Water Resource, Bhubaneswar, 2011; 27p.