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Long term rainfall analysis and crop planning for Jagdalpur region of Chhattisgarh

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Abstract
The available daily rainfall data of 40 years (1980-2019) at SGCARS, Kumarawand, Jagdalpur, District Bastar was examined for long term rainfall averages on weekly basis for Kharif season and its temporal variability. Coefficient of variation of 24.14 per cent indicated that the season's weekly rainfall was more or less stable over the years. The contribution to annual rainfall was 85.57 percent during Kharif season. Within the weeks, 30th week (23rd July to 29th July) was recorded as the highest rainfall contributing week with 8.16% followed by 26th week (25th June to 1st July) with 7.78% of total season's weekly rainfall. Mean weekly precipitation amount and its assurance reaches the peak (>65 mm/week) during 25th SMW to 33rd SMW which is classified as heavy rainfall and again declined thereafter. In week 28th continuity of rainfall (<20mm) is recorded for over 39 years. There is an ample scope of rain water to cultivate crop as rainfed kharif crop and also for rain water harvesting from July to September which can be utilized as crop saving irrigation as well as pre-sowing irrigation for succeeding rabi crops which are generally sown on residual soil moisture.

Keywords: Rainfall, rice, dry and wet spell, rainfall period, rainfall dependability

1. Introduction
During monsoonal period more than 75% of annual rainfall is received over a major portion of the country. India's economy has traditionally been agricultural in nature and excess climate anomalies, deficient and flooded rainfall years have a dramatic impact on the economy as well as on the living conditions of the inhabitants of the affected regions (Parthasarthy *et al*. 2017). As changing climate and erratic distribution of rainfall and increased field water losses account for unreliability and shortage of water for crop production, here stress has been laid on regional climate change. Most of precipitation occurs between June to September and during this period about 50% of rainfall occurs in about 20-30 hours (Pishroty, 2014). A large amount of water from these storms is lost by runoff, seepage and percolation. According to Gates (1996), experience of the world is sufficient to convince people that even a temporary change of climate can have profound impact on agricultural production and on the use of energy and water resources. Water stresses are a common feature during growth cycle of crops. Jagdalpur is a city situated in south eastern Chhattisgarh, India and stretches between 19.0854° N Latitude and 82.0183° E Longitude with elevation of 552 m mean sea level. It covers total agricultural area of about 1.74 lakh hectare with 1.68 lakh hectare in Kharif season and rice crop is grown in 1.30 lakh hectares (Govt. of Chhattisgarh, 2017) and rain fed rice production has always had an upper hand in this region. Since rainfall is the only source of moisture, the distribution of rain holds the key in determining the fate of entire crop productivity in the region. Knowledge of average monthly, weekly, seasonal and annual rainfall is helpful in understanding the general picture of the particular region but the weekly rainfall data analysis gives more useful and precise information for the rainfall based crop planning (Tiwari *et al*., 1992) [14]. Rainfall probabilities (wet and dry spells) could be made use of in selection of different cropping systems (Jadhav *et al*., 1999) [7]. The coincidence of wet spells with the sensitive phenophases sometimes may be more detrimental to the crop development. On the other hand, the occurrence of dry spell at the time of ripening would become beneficial. Therefore, the probabilities of wet and dry spells can serve as a basic input for establishing precise crop-weather relationships to take some useful decisions for crop management practices, contingent crop planning and related farm operations for sustaining crop production in the area.

Daily rainfall and rainfall on different timescale plays a great role in weather phenomena in tropical countries and helps to determine the Agricultural land use potential and hydrological investigations. This type of understanding is of more relevance in rain fed area where crop productions depend on vagaries of monsoon and other climatic parameters. Therefore rainfall distribution pattern is a major determinant of crop yield in rain fed areas. In this context, collection, scrutiny and analysis of historical weather data available in the region are essential to characterize the agricultural climate of the region. Such an analysis has also been reported from other parts of the country to follow a profitable crop planning system under rain fed conditions (Dingre and Habib, 2006) [5]. Hence, an attempt has been made to analyse the weekly rainfall data of Jagdalpur for evolving rainfall based strategies for kharif crops.

2. Materials and Methods

2.1 Study area

Jagdalpur is the district headquarter of Bastar which is in Chhattisgarh state. Jagdalpur has a tropical savanna climate (*Trewartha* climate classification *Aw*) with three main seasons: summer, monsoon and winter. Summers last from March to May and are hot, with the average maximum for May reaching 38.1 °C. The weather cools off somewhat for the monsoon season from June to September, which features very heavy rainfall. Winters are warm and dry. Average anural rainfall ranges from 1300-1500 mm (Bhelawe *et al*) [2]. The daily rainfall data for 40 years (1980-2019) recorded at Agro-meteorological Observatory, (19.0854° N 82.0183° E and 552 m above mean sea level), SGCARS for Jagdalpur region, Bastar, Chhattisgarh and this region is examined for analysing rainfall distribution pattern of the area, probability of wet and dry spells and its implications for crop planning

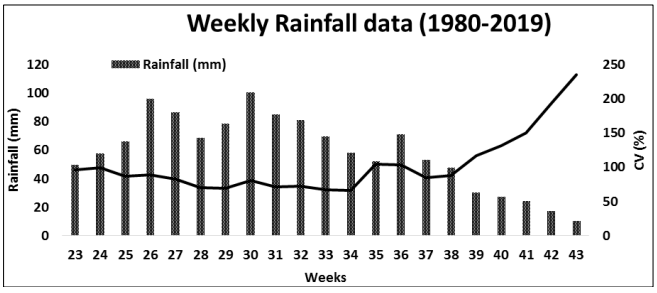

Fig 1: Graph showing mean season's weekly rainfall distribution of Jagdalpur (1980-2019)

2.2 Forecasting of wet and dry spell and weekly averages

The concept of estimating probabilities with respect to a given amount of rainfall is extremely useful for agricultural planning. In a crop growing season, many times decisions have to be taken based on the probability of receiving certain amount of rainfall during a given week [P(W)], which are called "initial probabilities". Then the probability of rain next week, if we had rain this week [P (W/W)] etc. are very important and are called "conditional probabilities". These initial and conditional probability becomes the basis for the analysis of rainfall using Markov chain process. An attempt has been made to use a standard week in dry spell, wet spell and rainfall analysis using Markov Chain Model and planning crops accordingly.

The following definitions have been employed:

1. A day receiving at least 2.5 mm or more rainfall from 08:30 to 08:30 IST the next day is defined as a wet day. Otherwise, the day is counted as a dry day (Agarwal *et al*.).
2. A week is wet if it receives 20 mm or more rainfall, otherwise dry (Pandarinath).

The initial probability of a week being dry is defined by:

P (D) = F (D)/N

where, P(D) is probability of the week being dry; F(D) is frequency of dry weeks; N is the total number of years of data being used.

Thus initial probability of the week being wet is given as:

P (W) = F (W)/N

Where, P (W) is probability of the week being wet; F (W) is frequency of dry weeks. The transitional probability of week being dry preceded by another dry week is:

P (D/D) = F (DD)/F (D)

where, P(D/D) is probability of the week being dry preceded by another dry week; F(D/D) is frequency of dry weeks preceded by another dry week. The transitional probability of week being wet preceded by another wet week is: P (W/W) = F (WW)/F (W)

where, P(W/W) is probability of the week being wet preceded by another wet week; F(WW) is frequency of wet weeks preceded by another wet week; F(W) is frequency of wet weeks.

A week receiving less than 20 mm rainfall is taken as dry spell week and a week receiving 20 mm or more rainfall as a wet week (Subramaniam and Raju, 1988). From the daily rainfalll data, weekly total rainfall was worked out for each year. The probability of occurrence of a dry week {p (d)}, two consecutive dry weeks {p (dd)} and {p (w)} wet week, {p (ww)} two consecutive wet week was computed by Markov Chain process (Robertson, 1976).

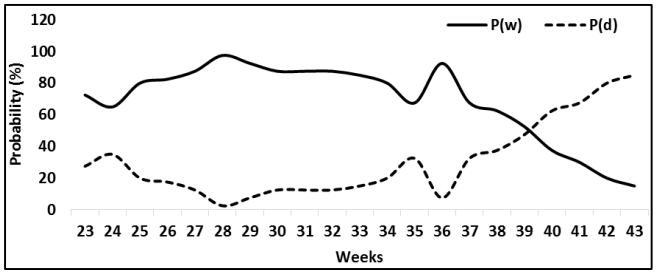

Fig 2: Graph representing probability of wet and dry weeks for season's week.

Further MS-Office Excel package is used to find out the mean and CV of rainfall over the 40 years.

Weekly Kharif season rainfall is further classified according to the intensity of rainfall which is given by India Meteorological Department. The weekly rainfall classification is tabulated in Table 1.

Table 1: Classification of rainfall intensity (mm) within 24 hours according to IMD

Particulars	Intensity (mm) within 24 hours
Trace	0.01-0.1
Very Light	0.1-2.4
Light	2.5-7.5
Moderate	7.6-35.5
Rather Heavy	35.6-64.4
Heavy	64.5-124.4
Very heavy	124.5-244.4
Extremely Heavy	244.5

3. Result and Discussion

3.1 Weekly rainfall (mm)

The weekly average season's rainfall ranges from 10.20 mm (43rd SMW) to 100.60 mm (30th SMW). Mean weekly precipitation amount and its assurance was high from 23rd SMW to 38th SMW, reaches the peak (>60 mm/week) during 25th SMW to 33rd SMW and again declined thereafter. The CV values during these period were relatively less (67–86%) owing to stable quantum of rainfall compared to the values of 65.67 – 235.27 during Kharif season (21 weeks), (Fig1). The higher values of CV in all weeks indicated that the rainfall was much erratic in distribution and it was higher during 39th SMW to 43rd SMW.

Long-term analysis of season's weekly rainfall data (1980-2019) indicated that Jagdalpur receives a mean annual rainfall of 1231.66 mm during Kharif season in past 40 years which was 85.57% of mean annual rainfall of Jagdalpur and season's lowest is recorded as 10 mm which was 0.82% of season's mean rainfall in week 43rd to as high as 100.60 mm which was 8.16% of season's mean rainfall in week 30th. (Table 2.)

Table 2: On basis of 40 years (1980-2019) average weekly rainfall

Weeks	Average rainfall (mm)	Classification	SD	CV (%)	Percentage of total rainfall
23	49.49	Rather Heavy	47.77	96.52	4.01
24	57.80	Rather Heavy	57.24	99.03	4.68
25	66.41	Heavy	57.72	86.92	5.38
26	95.91	Heavy	79.91	88.53	7.78
27	86.42	Heavy	71.84	83.13	7.01
28	68.45	Heavy	47.81	69.85	5.55
29	78.73	Heavy	54.36	69.04	6.38
30	100.60	Heavy	81.06	80.57	8.16
31	84.99	Heavy	60.49	71.17	6.89
32	81.3	Heavy	58.85	72.38	6.59
33	69.47	Heavy	46.55	67.00	5.63
34	58.17	Rather Heavy	38.20	65.67	4.71
35	52.36	Rather Heavy	54.86	104.79	4.24
36	70.95	Heavy	73.33	103.35	5.75
37	53.11	Rather Heavy	44.84	84.43	4.30
38	47.87	Rather Heavy	41.83	87.37	3.88
39	30.17	Moderate	35.18	116.62	2.44
40	27.40	Moderate	35.89	130.98	2.22
41	24.26	Moderate	36.38	149.93	1.96
42	17.53	Moderate	34.04	194.22	1.42
43	10.20	Moderate	24.01	235.27	0.82
AVG	1231.66				
TP	85.57%				

3.2 Probability of dry and wet weeks

The probability of occurrence of dry spells (Table 3) is as high as 80-85 per cent in 42nd and 43rd SMW. Thereafter, the values remain low between 23rd to 38th SMW (representing wet spell sequence) and probability of getting dry spell and two consecutive dry spell is high (>50%) during 40 SMW to 43 SMW and in 33rd SMW. On the other hand, the probability of getting rainfall (wet spell) remains very high (80-97.5%) during 25th to 34th SMW, then decreases until 41st SMW. The probability of getting a wet spell and two consecutive wet spells are low (<40%) during 39th SMW to 43rd SMW. The values remained high (>80%) during 27th to 34th SMW and in 36 SMW. (Fig 2)

Table 3: The probability of occurrence of dry and wet spells during kharif season

Standard meteorological week	Average rainfall (mm)	P(w)	P(ww)	P(d)	P(dd)
23	49.49	72.5	68.96	27.5	9.090
24	57.80	65	57.69	35	28.57
25	66.41	80	75	20	12.5
26	95.91	82.5	78.78	17.5	14.28
27	86.42	87.5	82.85	12.5	0
28	68.45	97.5	94.87	2.5	0
29	78.73	92.5	89.18	7.5	0
30	100.60	87.5	82.85	12.5	0
31	84.99	87.5	85.71	12.5	0
32	81.3	87.5	82.85	12.5	0
33	69.47	85	91.17	15	50
34	58.17	80	84.37	20	25
35	52.36	67.5	70.37	32.5	23.07
36	70.95	92.5	89.18	7.5	0
37	53.11	67.5	66.66	32.5	30.76
38	47.87	62.5	56	37.5	26.66
39	30.17	52.5	38.09	47.5	31.57
40	27.40	37.5	26.66	62.5	52
41	24.26	30	33.33	67.5	55.55
42	17.53	20	12.5	80	78.12
43	10.20	15	0	85	85.29

3.3 Crop planning

Based on the above analysis, the following recommendations for the region could be made to increase the crop production per unit area under rain fed conditions. About 85 per cent of the total average annual rainfall coincides with kharif season and is received during a short time span of two and half months between second fortnights of June to September due to south-west monsoon. Pre monsoon rainfall received during April–May can be utilized for summer ploughing to make the land ready for final field preparation. Further, the soils of Bastar region are deficit in nutrients content; hence the moisture which was received during April-May should be utilized for sowing of green manure crops. The possibility of direct seed rice by seed drill with proper depth and spacing also occurred so that the crop dose not face dry spell during critical growth period. More over with the normal onset of rainfall, sowing of main season kharif crop like rice, maize and pigeon pea should be started in the first fortnight of June.

In case of rice, early and late variety last 60 to 110 days and 140 to 160 days respectively. Rice require total of 1100 to 1250 mm water for growth i.e. from vegetative to ripening stages. Reproductive stage and ripening stage lasts 30 days each, but vegetative stage differs in early and late variety of rice. This makes the difference in critical growth stages in both the varieties of rice. The rice has three critical growth stages *viz.* Tillering, Panicle initiation and Booting in which the irrigation is necessary. Tillering stage comes after 25 to 30 DAS in both early and late varieties, Panicle initiation comes after 55 to 60 DAS and 70 to 80 DAS in early and late variety, respectively and Booting stage comes after 70 to 75 DAS and 85 to 90 DAS in early and late variety, respectively. The rainfall during these stages in both early and late variety is ample i.e. 58.17 to 100.60 mm in this region (Table 4). Thus, this concludes for cultivation of rice, there is adequate water availability and will provide a good yield in rain fed condition in Jagdalpur region.

Table 4: Critical growth stages of important crops with their coincidence with standard meteorological week rainfall

Standard Meteorological Week	Average rainfall (mm)	Name of Important kharif crops			
		Maize	Pigeon Pea	Rice	
				Early	Late
23	49.49				
24	57.80				
25	66.41				
26	95.91		Branching	Tillering	Tillering
27	86.42		Branching	Tillering	Tillering
28	68.45				
29	78.73				
30	100.60			Panicle	
31	84.99	T/S		Panicle	
32	81.3	T/S	FI		Panicle
33	69.47		FI	Booting	Panicle
34	58.17			Booting	
35	52.36	Dough			Booting
36	70.95	Dough			Booting
37	53.11				
38	47.87		Pod Dev		
39	30.17		Pod Dev		
40	27.40				
41	24.26				
42	17.53				
43	10.2075				

Likewise in case of Maize critical growth stages are Tasseling (55 to 65 DAS), Silking (66 to 76 DAS) and Dough (77 to 87 DAS) stage in which irrigation is important, during these stages rainfall is sufficient (52 to 95 mm) to be grown as rain fed crop (Table 4). Inter-cropping of maize (50/60cm) with pulses (green gram/black gram) in 1:1 row proportion can be viable option for increasing per unit area crop productivity under rain fed conditions.

Pigeon pea is also a major crop of Bastar, grown for over 3.39 thousand ha. It is also a kharif season crop but with comparatively less water requirement than other crops. In Pigeon pea also, there are three critical stages *viz.* Branching (30 DAS), Flower initiation (70 to 75 DAS) and Pod development (110 to 115 DAS), in which irrigation is necessary. The rainfalls during these stages were between 30.17 to 95.91 mm which is enough for the cultivation of pigeon pea in this region (Table 4).

In the event of mid-season dry spell, mulching will help in reducing soil evaporation and conserving moisture in top layers of the soil. A major portion of monsoon rainfall is generally lost through runoff (30 to 40%), which can be stored through the construction of suitable water harvesting structures as on-farm reservoirs. The rainfall received during October-November is only 4 to 5 per cent of the total average annual rainfall which is very low for the sowing of rabi season crops. Therefore, soil and moisture conservation measures need due attention to conserve rainwater particularly during the months of July to September. Sowing of main rabi season crops like wheat, winter maize, mustard, gram and seasonal vegetables should be started from the last week of October to November.

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