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Assessment of rainfall probabilities for crop planning in Balod district of Chhattisgarh

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Abstract
In the present study, assessment of rainfall probabilities was carried out on weekly basis of 30 years daily rainfall data for the period 1989-2019. The observed values were computed by using Markov chain model. The initial probability of occurrence of wet weeks was higher during SMWs 28th to 35th. The range of probability of wet week varied from 61.3% to 71.0%. The conditional probability of occurrence of wet week preceded by wet weeks was higher during SMWs 27th to 36th. The range of probability of wet week varied from 50.0% to 79.0%. The probability of occurrence of two and three consecutive wet weeks was higher during SMWs 28th to 33rd. The range of probability of wet week varied from 22.0% to 33.1%. Results showed that the 24th to 26th SMW should be used for field preparation and kharif crop sowing. Dryland crop planting in the rabi season may be finished between the 40th and 42nd SMW as the further weeks have a less probability of receiving enough rainfall.

Keywords: Markov chain model, initial probability, conditional probability, consecutive wet week probability

Introduction
One of the most interesting aspects of weather is rainfall and its variance from one place to another. The amount of rainfall received over an area is an important factor in assessing the amount of water available to meet the various demands for agriculture, industry, irrigation, hydroelectric power generation and other human activities. Therefore, distribution of rainfall in time and space is an important factor in determining the economical status of a region or a state or a nation. Indian agriculture is mostly rainfed (around 60 % of arable land) and monsoon plays a major role not only in agriculture but also in allied day to day activities. Rainfall due to its erratic nature is considered as the major yield limiting factor in the tropical countries particularly in case of rainfed farming. During monsoonal period, more than 75% of annual rainfall is received over a major portion of the country. The monsoon rainfall pattern has changed now a days as a consequence of climate change and thereby resulting in frequent early, mid or late season droughts. Sequence of dry and wet periods along with the onset and withdrawal of monsoon rainfall determine the success or failure of a crop (Dash and Shathpathy, 2018) [2]. Studies on rainfall, particularly its unpredictability and frequency on a weekly basis, provide more data for planning rainfed crops. Any agricultural program's planning and execution tactics must take the region's rainfall into account. Therefore, accurate and detailed information on the pattern of rainfall distribution over a time for a given location is vital for proper and optimal planning of the required irrigation system and cropping pattern.
The Markov chain model is used to describe the probabilities of rainfall. With the help of statistical approaches, probability analysis can be used to predict the occurrence of future events based on records of rainfall. Scientific prediction of rains and crop planning done analytically may prove a significant tool in the hands of farmers for better economic returns. Generally, the cropping pattern is suggested considering the rainfall probabilities at different levels. A consistent pattern of rainfall is typically necessary for healthy plants; too much or too little rainfall can be harmful or even devastating for crops. Rainfall requirements for crops vary depending on difficult conditions. The weekly study of rainfall will be very helpful for agricultural planning, whereas the yearly and seasonal analysis of rainfall will provide a general idea about the region's rainfall pattern.
Dugal *et al*. (2018) [3] revealed that the Bhadrak district, the initial rainfall probability {P(W)} of receiving 20 mm of rainfall per week was greater than 30% during the 22nd SMW. This week is better suited for crop sowing because the initial and conditional probabilities of a wet week followed by a wet week {P (W/W)} were both greater than 50% in the 23rd SMW.

The probability of receiving 10 mm of rain per week during the 44th to 46th SMW (29th October to 18th November) was more than 30%. Land preparation and the planting of rabi crops are appropriate during this time.

Materials and Method

Description of the study area

Chhattisgarh is located in the central part of India. Chhattisgarh state, stretches across the longitudinal meridian of 80^0 15' E to 84^0 20' East and latitudinal expanse of 17^0 46'N to 24^0 5' North. The state has three agro-climatic zones are Chhattisgarh plains, Bastar plateau and Northern Hills region spreading over a geographical area of about 13.60 million hectares.

The three main seasons in Chhattisgarh are summer, monsoon and winter. The average annual rainfall is 1400 millimetres. The majority of Chhattisgarh experiences a tropical, humid and sub-humid climate. Due to its location near the Tropic of Cancer, the central region of Chhattisgarh is extremely hot. The eastern and southern regions are humid.

Methodology

Database: Daily rainfall and temperature data was collected from Department of Agrometeorology IGKV Raipur for a period of 30 years (1989-2019). Data quality checked through MS Excel software and data conversion and rainfall quantum (Initial, conditional and consecutive dry and wet probability) by using Markov chain model through a Weather Cock software (Rao *et al.*, 2011) [5]. The 50 mm limit will be taken because on the basis of agroclimatic onset criteria 3-day accumulated rainfall ≥ 50 mm.

Initial rainfall probability of a week being dry or wet

P(D) = F(D)/N; P(W) = F(W)/N

Where, P(D) = probability of occurrence of dry week, P(W) = probability of occurrence of wet week, F(D) = frequency of occurrence of dry week, F(W) = frequency of occurrence of wet week, N = total number of years.

Conditional probability of a week being dry or wet

P(D/D) = F(DD)/F(D); P(W/W) = F(WW)/F(W); P(W/D) = 1-P(D/D); P(D/W) = 1-P(W/W)

where, P(D/D) = probability of a week being dry preceded by another dry week, F(DD) = frequency of dry week preceded by another dry week, P(W/W) = probability of a week being wet preceded by another wet week, F(WW) = frequency of a wet week preceded by another wet week, P (W/D) = probability of a wet week preceded by a dry week, and P(D/W) = probability of a dry week preceded by a wet week.

Consecutive dry and wet week probabilities

P(2D) = P(DW1) ×P(DDW2); P(2W) = P(WW1) ×P(WWW2)

where, P(2D) = probability of two 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(2W) = probability of two 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.

Results and Discussion

Probability Distribution of Balod district at 50 mm

The results of initial and conditional probabilities of dry and wet weeks and consecutive dry and wet weeks are presented in Table 1. The results are discussed in relevance with rainy season (23th SMW –45th SMW). The initial probability of getting wet and dry week P(W) and P(D), respectively ranges from 0.00 to 71.0 percent and 29.0 to 100.0 percent.

The conditional probability of occurrence of wet week preceded by wet week [P(W/W)], dry week preceded by wet week [P(D/W)], dry week preceded by dry week [P(D/D)] and wet week preceded by dry week [P(W/D)] during monsoon season (23rd to 45th SMW) values vary from 0.00 to 79.0, 0.00 to 100. 0, 20.0 to 100.0 and 0.00 to 80.0 percent respectively.

The probability of occurrence of two and three consecutive dry weeks was varying from 6.5 to 100.0 and 1.9 to 100.0 percent respectively. Similarly, consecutive probability of two and three wet weeks was varying from 0.00 to 48.4 and 0.00 to 33.1 percent respectively.

Table 1: Weekly initial, conditional and consecutive dry and wet week probabilities of rainfall in Balod district at 50 mm

SMW	Initial Probability (%)		Conditional Probability (%)				Consecutive Dry and Wet Probability (%)			
	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	2D	3D	2W	3W
23	6.5	93.6	0.0	0.0	93.6	6.5	71.0	43.2	3.2	1.2
24	25.8	74.2	50.0	50.0	75.9	24.1	45.2	23.8	9.7	4.0
25	38.7	61.3	37.5	62.5	60.9	39.1	32.3	19.0	16.1	8.1
26	45.2	54.8	41.7	58.3	52.6	47.4	32.3	13.3	22.6	14.5
27	45.2	54.8	50.0	50.0	58.8	41.2	22.6	5.7	29.0	19.9
28	61.3	38.7	64.3	35.7	41.2	58.8	9.7	3.2	41.9	24.8
29	71.0	29.0	68.4	31.6	25.0	75.0	9.7	4.8	41.9	33.1
30	61.3	38.7	59.1	40.9	33.3	66.7	19.4	3.9	48.4	30.0
31	67.7	32.3	79.0	21.1	50.0	50.0	6.5	1.9	41.9	22.0
32	67.7	32.3	61.9	38.1	20.0	80.0	9.7	6.0	35.5	23.7
33	58.1	41.9	52.4	47.6	30.0	70.0	25.8	9.2	38.7	22.8
34	54.8	45.2	66.7	33.3	61.5	38.5	16.1	9.4	32.3	17.0
35	61.3	38.7	58.8	41.2	35.7	64.3	22.6	16.9	32.3	6.5
36	48.4	51.6	52.6	47.4	58.3	41.7	38.7	29.0	9.7	2.8
37	22.6	77.4	20.0	80.0	75.0	25.0	58.1	53.0	6.5	0.0
38	25.8	74.2	28.6	71.4	75.0	25.0	67.7	63.1	0.0	0.0
39	6.5	93.6	0.0	100.0	91.3	8.7	87.1	78.1	0.0	0.0
40	6.5	93.6	0.0	100.0	93.1	6.9	83.9	80.8	3.2	0.0
41	12.9	87.1	50.0	50.0	89.7	10.3	83.9	83.9	0.0	0.0
42	3.2	96.8	0.0	100.0	96.3	3.7	96.8	96.8	0.0	0.0

43	0.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	0.0
44	0.0	100.0	0.0	0.0	100.0	0.0	100.0	96.8	0.0	0.0
45	0.0	100.0	0.0	0.0	100.0	0.0	96.8	96.8	0.0	0.0

Conclusion

This study found out the chance of weeks for appropriate crop planning and occurrence of probability. Before onset of monsoon the initial, conditional and consecutive dry week probability observed was high, hence this period was suitable for summer ploughing. Land preparation for planting crops could be undertaken between 24th SMW and 26th SMW weeks for the main rainy season crops cultivation. This period is ideal for growing short duration rice crop and non-paddy crops like maize, urid, greengram, groundnut, arhar and soybean in upland during kharif season. Land preparation and sowing of rabi pulses and oilseed under rainfed condition should be completed in the SMW 40th to 42nd on residual moisture. After that sowing of rabi crops without supplemental irrigation would be risky.

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