Dry and wet spell probability analysis by Markov chain model for Kohima (Nagaland), India

Parmendra Prasad Dabral *, Mitu Dada, Hibu Odi

(*Department of Agricultural Engineering, North Eastern Regional Institute of Science and Technology (Deemed to be University), Nirjuli (Itanagar)-791109, Arunachal Pradesh (India)*)

Abstract: It is important to know the sequence of dry and wet periods for crop planning and to carry out the agricultural practice of a region. This study is undertaken with the objectives of forecast dry and wet spell analysis using Markov Chain Model for Kohima (Nagaland). The results indicated that the probability of occurrence of dry week is higher from week no. 1 to 16 and also from week numbers 41 to 52. The range of probability of occurrence of dry week in these weeks varies from 55.56 to 100 per cent. The probability of occurrence of dry week preceded by another dry week is higher in week no.1 to 13, 15, 41, 43, and 52. The range of probability occurrence of dry week preceded by another dry week in these weeks is ranging from 36.36 to 50%. There is from 22.22 to 50%, the probability that two consecutive dry weeks would occur from week numbers 1 to 13, 15, 41 and 43 to 52. The probability of occurrence of three consecutive dry weeks was found very low varying from 0 to 16.67%, in most of the week.

Keywords: Dry and wet spell probability, Markov chain model, Kohima (Nagaland)

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1 Introduction

Coincidence of dry spell with sensitive phonological stages of the crop affects crop yield. Hence, for the purpose of crop planning and to carry out the agricultural practices it is important to know the sequence of dry and wet periods (Pandarinath, 1991). The Markov Chain Model is based on the transitional probability describing a situation that changes between two stages. In other words, the current probability of certain state depends on the probability of the immediately preceding state only (Gerald, 1976). The Markov Chain Model has been extensively used to study spell distribution and other properties of rainfall occurrence (Garbriel and Newmann, 1962), the long term frequency behaviour of wet and dry weather (Victor and Sastry, 1979) as well as for computation of probability of occurrence of daily precipitation (Stern, 1982).

Pandarinath (1991), Rath *et al.* (1996), Singh and Bhandari (1998), Panigrahi and Panda (2002), Jat *et al.* (2003), Dabral and Jhajharia (2003), Dingre (2007), Subash *et al.* (2009), Dabral *et al.* (2014), Pali and Thakur (2015), Joseph and Tamilmani (2017) applied Markov chain model for calculating initial and conditional probability of dry and wet spells of different duration for various climatic situations and have evaluated its importance in crop planning.

Nagaland is a mountainous state of North-East India, which lies between 25.67° N latitudes and 94.12°E longitude. Kohima (Nagland), India is the capital of Nagaland. It has an average elevation of 1261 m. Kohima town is located on the top of a high ridge and the town serpentines all along the top of the surrounding mountain ranges as is typical of most Naga settlements. The total area of the district is 1595 km^2. The major share of the showers received during April to September is around 1600 mm. During December normally no rainfall in received. However, during January to March the rainfall is very low. No systematic information was available about dry/wet spell analysis for Kohima. Hence, the

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*** Corresponding Author:** PARMENDRA PRASAD DABRAL, Department of Agricultural Engineering, NERIST, NIrjuli-791109, Arunachal Pradesh, India. Email: ppdabral1962@gmail.com.

present study was taken with the objective to forecast weekly dry and wet spells using Morkov Chain model.

2 Methods and Material

2.1 Study area and collection of data

Daily rainfall data recorded at the meteorological observatory, Kohima supplied by the Directorate of Soil and Water Conservation. Kohima (Nagaland, India for 18 years (1997-2014) have been used in this analysis. The daily data, in a particular year, has been converted to weekly data.

2.2 Forecasting of dry and wet spells using Markov Chain model

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 a 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 probabilities become the basis for the analysis of rainfall using Markov chain process.

The following definitions have been employed in this section:

1. A day receiving at least 2.5 mm or more rainfall from 0830 to 0830 IST the next day is defined as wet day. Otherwise the day is counted as a dry day (Agarwal *et al*., 1984).

2. A week is wet if it receives 20 mm or more rainfall, otherwise dry (Pandarinath (1991) and Dash and Senapati (1992).

The different notations followed in the Markov Chain Analysis are given below:

The initial probability: P(D)=F(D)/N, P(W)= F(W)/N

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 dry weeks and N=total number of years of data being used.

The transition probabilities : P(D/D)=F(DD)/F(D); P(W/W)=F(WW)/F(W); P(D/W)=1–P(W/W); P(W/D)=1–P(D/D)

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

The consecutive dry probabilities: (2D)=P(Dw_1)× P(DDw_2); P(3D)= P(Dw_1)×P(DDw_2)×P(DDw_3)

where, P(2D)=probability of two consecutive dry weeks; P(Dw_1)=probability of the first week being dry; and P(DDw_2)=probability of the second consecutive dry week given the preceding week being dry; P(3D)=probability of three consecutive weeks; P(DDw_3)=probability of third week being dry given that preceding week dry.

The consecutive wet probabilities: (2W)=P(Ww_1)× P(WWw_2):P(3W)=P(Ww_1)×P(WWw_2)×P(WWw_3)

where, P(2W)=probability of two consecutive weeks; P(Ww_1)=probability of the first week being wet; P(WWw_2)=probability of the second consecutive wet week given the preceding week being wet; P(3W)= probability of three consecutive wet weeks; P(WWw_3)= probability of third week being wet given that preceding week wet.

3 Results and discussion

The mean annual rainfall of Kohima for the past 18 years (1997-2014) was found to be 1660.8 mm with standard deviation 253.9 mm and coefficient of variation 15.3%. The annual rainfall amount ranged from 1242.2 mm (the lowest during the year 1997) to 2003.7 mm (the highest during the year 2007). Out of 18 years, 10 years recorded annual rainfall in excess of average (1660.8 mm) while 8 years recorded below average rainfall (Figure 1). Weekly rainfall data of 18 years (1997-2014) indicated that there exist vary low variability of CV<10% (Figures. 2 and 3). The weekly rainfall variability indicated that mean weekly rainfall was <20 mm during 1 to 14 SMW (standard meteorological week) and 43 to 52 SMW (Figure 2). The mean weekly rainfall showed that 15 to 43 weeks are considered as a more stable period and total average length of rainy period is 29 weeks at Kohima. The weekly contribution of rainfall towards annual average rainfall is found to be highest during 15 to 43 SMW accounting 90.8% of the average annual rainfall.

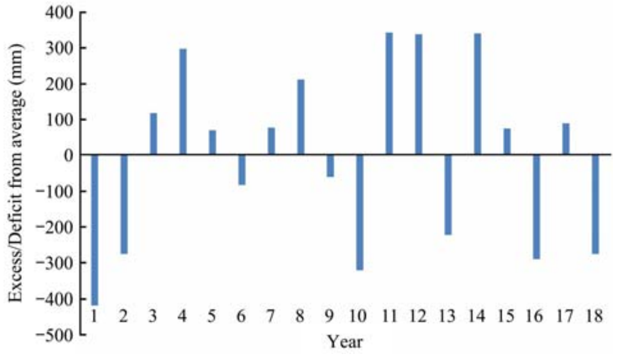

Figure 1 Annual variability of rainfall over average in Kohima (1997-2014)

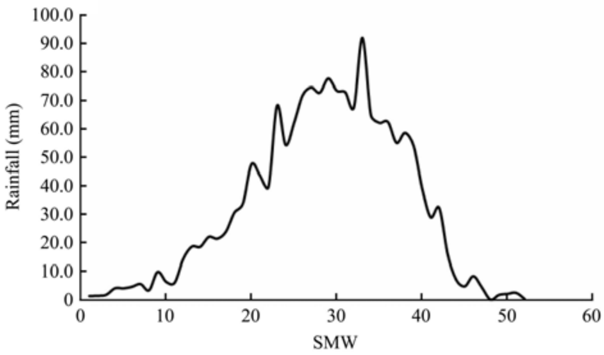

Figure 2 Weekly rainfall distribution of Kohima (1997-2014)

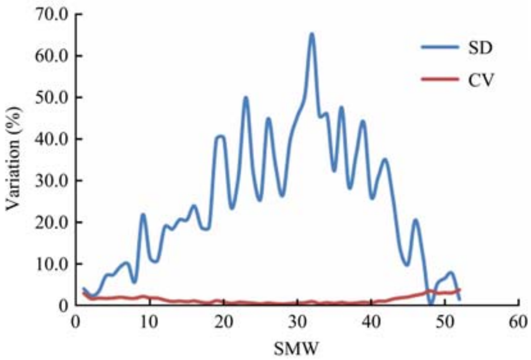

Figure 3 Weekly rainfall variability of Kohima (1997-2014)

3.1 Weekly dry and wet Spells

3.1.1 Initial and transitional dry and wet week probability analysis

Probability of occurrence of dry week is higher from week no. 1 to 16 and also from week no. 41 to 52 (Table 1). The range of probability of occurrence of dry week in these weeks varies from 55.56 to 100%. The probability of occurrence of dry week preceded by another dry week is higher in week number 1to13, 15, 41, 43 to 52. The range of probability occurrence of dry week preceded by another dry week in these weeks is ranging from 36.36 to 50%. The range of probability of occurrence of dry week preceded by wet week is 88.89 to 100% in week numbers. 1 to 9, 11 and 43 to 52 (Table 1).

Table 1 Initial and transitional probabilities of dry and wet week

Week	Initial Probabilities (%)		Transitional Probabilities (%)			
	P(W)	P(D)	P(W/W)	P(D/D)	P(D/W)	P(W/D)
1	0	100	0	50	100	50
2	0	100	0	50	100	50
3	0	100	0	50	100	50
4	5.56	94.44	0	47.06	100	52.94
5	5.56	94.44	0	47.06	100	52.94
6	5.56	94.44	0	47.06	100	52.94
7	5.56	94.44	0	47.06	100	52.94
8	0	100	0	50	100	50
9	5.56	94.44	0	47.06	100	52.94
10	22.22	77.78	0	35.71	100	64.29
11	5.56	94.44	0	47.06	100	52.94
12	22.22	77.78	25	42.86	75	57.14
13	38.89	61.11	28.6	36.36	71.4	63.64
14	38.89	61.11	0	18.18	100	81.82
15	38.89	61.11	28.6	36.36	71.4	63.64
16	44.44	55.56	12.5	20	87.5	80
17	61.11	38.89	27.3	14.29	72.7	85.71
18	66.67	33.33	25	0	75	100
19	72.22	27.78	30.8	0	69.2	100
20	72.22	27.78	30.8	0	69.2	100
21	72.22	27.78	30.8	0	69.2	100
22	72.22	27.78	30.8	0	69.2	100
23	88.89	11.11	50	50	50	50
24	83.33	16.67	40	0	60	100
25	100	0	50	0	50	100
26	94.44	5.56	47.1	0	52.9	100
27	94.44	5.56	47.1	0	52.9	100
28	100	0	50	0	50	100
29	100	0	50	0	50	100
30	94.44	5.56	47.1	0	52.9	100
31	94.44	5.56	47.1	0	52.9	100
32	77.78	22.22	35.7	0	64.3	100
33	100	0	50	0	50	100
34	83.33	16.67	40	0	60	100
35	94.44	5.56	94.4	0	5.6	100
36	83.33	16.67	83.3	0	16.7	100
37	88.89	11.11	88.9	0	11.1	100
38	83.33	16.67	83.3	0	16.7	100
39	77.78	22.22	77.8	0	22.2	100
40	72.22	27.78	72.2	20	27.8	80
41	38.89	61.11	38.9	36.36	61.1	63.64
42	66.67	33.33	66.7	16.67	33.3	83.33
43	16.67	83.33	16.7	40	83.3	60
44	11.11	88.89	11.1	43.75	88.9	56.25
45	5.56	94.44	5.6	47.06	94.4	52.94
46	11.11	88.89	11.1	43.75	88.9	56.25
47	5.56	94.44	5.6	47.06	94.4	52.94
48	0	100	0	50	100	50
49	5.56	94.44	5.6	47.06	94.4	52.94
50	5.56	94.44	5.6	47.06	94.4	52.94
51	5.56	94.44	5.6	47.06	94.4	52.94
52	0	100	0	50	100	50

Probability of occurrence of wet week is higher from week no. 17 to 40, 42. The range of probability of wet week varies from 61.11 to 100%. The probability of occurrence of wet week preceded by another wet week is higher from week no. 23, 25, 28, 29, 33, 35 to 40 and 42. The probability of occurrence of wet week in these weeks ranged from 50 to 94.4% (Table 1). Probability of wet week preceded by dry week is higher in week no. 1 to 52. The range of probability of occurrence of wet week in these weeks varies from 50 to 100% (Table 1).

Consecutive dry and wet week probability analysis

The analysis of consecutive dry and wet spells (Table 2) reveals that there is 22.22 to 50% probability that two consecutive dry weeks would occur from week numbers 1 to 13, 15, 41 and 43 to 52. Similarly, the probability of occurrence of three consecutive dry weeks was found very low varying from 0 to 16.67% in most of the week (Table 2).

The consecutive probability of two wet weeks varied from 22.2 to 89.2% for week no. 19 to 40 and 42. Consecutive probability of three wet weeks is 26.2% for week number 35 (Table 2).

Table 2 Consecutive dry and wet week probability analysis

Week	Consecutive dry probabilities (%)		Consecutive wet probabilities (%)		Week	Consecutive dry probabilities (%)		Consecutive wet probabilities (%)	
	P(2D)	P(3D)	P(2W)	P(3W)		P(2D)	P(3D)	P(2W)	P(3W)
1	50	16.67	0	0	27	0	0	44.4	13.1
2	50	16.67	0	0	28	0	0	50	16.7
3	50	16.67	0	0	29	0	0	50	16.7
4	44.44	13.07	0	0	30	0	0	44.4	13.1
5	44.44	13.07	0	0	31	0	0	44.4	13.1
6	44.44	13.07	0	0	32	0	0	27.8	6
7	44.44	13.07	0	0	33	0	0	50	16.7
8	50	16.67	0	0	34	0	0	33.3	6.7
9	44.44	13.07	0	0	35	0	0	89.2	26.2
10	27.78	3.97	0	0	36	0	0	69.4	13.9
11	44.44	13.07	0	0	37	0	0	79	19.8
12	33.33	7.14	5.6	0	38	0	0	69.4	13.9
13	22.22	6.06	11.1	3.2	39	0	0	60.5	8.6
14	11.11	1.01	0	0	40	5.56	0	52.2	8
15	22.22	4.04	11.1	0	41	22.22	4.04	15.1	0
16	11.11	0	5.6	0	42	5.56	0	44.4	3.7
17	5.56	0	16.7	3	43	33.33	6.67	2.8	0
18	0	0	16.7	2.8	44	38.89	12.15	1.2	0
19	0	0	22.2	1.7	45	44.44	13.07	0.3	0
20	0	0	22.2	3.4	46	38.89	9.72	1.2	0
21	0	0	22.2	3.4	47	48.44	13.07	0.3	0
22	0	0	22.2	3.4	48	50	16.67	0	0
23	5.56	0	44.4	13.9	49	44.44	13.07	0.3	0
24	0	0	33.3	6.7	50	44.44	13.07	0.3	0
25	0	0	50	16.7	51	44.44	13.07	0.3	0
26	0	0	44.4	13.1	52	50	16.67	0	0

Mishra (2007) stated that the two or more dry weeks during germination or after sowing, 2-4 dry weeks during the vegetative crop growth stage, 2 or more dry weeks during flowering and 4 or more weeks during grain filling or maturity have found to be disastrous.

The results reported above are different from Dabral and Jhajharia (2003) and Dabral *et al.* (2014) who has done the similar type of study, for Doimukh(Itanagar) and North Lakhimpur (Assam). The study reveals that week numbers 1 to 13 and 41 to 52 of the year remain under stress. Therefore, there is need of supplement irrigation for the major crop grown in the study area from 8th October to 1st April.

The results obtained in this study may be useful for water managements and crop planning of the study area.

4 Conclusions

Important conclusions of the study are as follows:

1. Probability of occurrence of dry week is higher from week no. 1 to 16 and also from week numbers. 41 to 52. The range of probability of occurrence of dry week in these weeks varies from 55.56 to 100%.

2. The probability of occurrence of dry week preceded by another dry week is higher in week no.1 to 13, 15, 41, 43-52. The range of probability occurrence of dry week preceded by another dry week in these weeks is ranging from 36.36 to 50%.

3. There is 22.22 to 50% probability that two consecutive dry weeks would occur from week numbers 1 to 13, 15, 41 and 43 to 52. The probability of occurrence of three consecutive dry weeks was found very low varying from 0 to 16.67% in most of the weeks.

4. The study reveals that week numbers 1 to 13 and 41 to 52 of the year remain under stress. Therefore, there is need of supplement irrigation for the major crop grown in the study area from 8th October to 1st April.

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