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Markov chain and incomplete Gamma distribution analysis of weekly rainfall over Navsari region of south Gujarat

NEERAJ KUMAR, S. S. PATEL, A. L. CHALODIA, O. U. VADAVIYA, H. R. PANDYA,
R. R. PISAL, K. K. DAKHORE and M. L. PATEL

Department of Agricultural Engineering, Navsari Agricultural University, Navsari – 396 450, Gujarat, India

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e mail : neeraj34012@gmail.com

सार – इस अध्ययन में मार्कोव चेन और अपूर्ण गामा विवरण विश्लेषण हेतु नवसारी क्षेत्र के लिए 34 वर्षों (1980-2013) के साप्ताहिक वर्षा के आँकड़ों का उपयोग किया गया है। इसमें नवसारी क्षेत्र के लिए वर्षा ऋतु में शुष्क और आर्द्र सप्ताहों की घटना की संभावनाओं का पता लगाने और वर्षा के साप्ताहिक विश्लेषण का अध्ययन किया गया। इसमें शुष्क सप्ताह के रूप में एक सप्ताह में 200 मि. मी., 40.0 मि. मी., 60.0 मि. मी., 80.0 मि. मी. और 100.00 मि. मी. से कम वर्षा तथा आर्द्र सप्ताह के रूप में 20.0 मि. मी., 40.0 मि. मी., 60.0 मि. मी., 80 मि. मी. और 100.0 मि. मी. या इससे अधिक वर्षा पर विचार करते हुए मार्कोव चेन मॉडल पर आधारित साप्ताहिक वर्षा के लिए शुष्क और आर्द्र दौर विश्लेषण किए गए। वर्षा ऋतु के समय से पहले और देरी से आने के सप्ताह क्रमश: 21 मानक मौसम विज्ञान सप्ताह (SMW) (21-27 मई) और 32 एस एम डब्ल्यू (06-12 अगस्त) थे। इसी प्रकार मॉनसूनोत्तर ऋतु के समय से पहले और देरी के सप्ताह 23 से 29 एस एम डब्ल्यू पर 40 एस एम डब्ल्यू (01-07 अक्तूबर) और 48 एस एम डब्ल्यू (26 नवम्बर-02 दिसम्बर) थे। अपूर्ण गामा वितरण प्रणाली का उपयोग करते हुए 10, 25, 50, 75 और 90 प्रतिशत स्तरों पर साप्ताहिक अंतरालों पर वर्षा की घटना की संभावना का आकलन किया गया। नवसारी क्षेत्र में साप्ताहिक वर्षा के लिए अपूर्ण गामा संभावित वितरण से कम से कम 1025.6 मि. मी. पर निश्चित वर्षा होने की 90 प्रतिशत की संभावना रही और 1523.6 मि. मी. वर्षा होने की 90 प्रतिशत की संभावना रही। इस विश्लेषण से प्राप्त परिणामों का उपयोग नवसारी क्षेत्र में कृषि योजना के लिए किया गया। सामान्यत: नवसारी क्षेत्र में धान के पौधे का रोपण मॉनसून प्रारम्भ होने के पश्चात 28 से 30 मानक मौसम विज्ञान सप्ताहों (एस एम डब्ल्यू) के दौरान किया गया जबकि गन्ने की बुआई 42 से 45 एस एम डब्ल्यू के दौरान की गई।

ABSTRACT. In the present study the weekly rainfall data of 34 years (1980-2013) for Navsari region were used for Markov Chain and incomplete gamma distribution analysis. The present study has been carried out to find the probabilities of occurrence of dry and wet weeks during rainy season and weekly analysis of rainfall for Navsari region. The dry and wet spell analysis was carried out for weekly rainfall based on Markov Chain Model considering less than 20.0 mm, 40.0 mm, 60.0 mm, 80.0 mm and 100.0 mm rainfall in a week as a dry week and 20.0 mm, 40.0 mm, 60.0 mm, 80.0 mm and 100.0 mm or more as a wet week. The earliest and delayed onset week of rainy season was 21 Standard Meteorological Week (SMW) (21-27 May) and 32 SMW (6-12 August), respectively. Similarly the earliest and delayed week of post-monsoon season was 40 SMW (1-7 October) and 48 SMW (26 November-2 December) during 23rd - 29th SMW. The probability of rainfall occurrence at weekly intervals at 10, 25, 50, 75 and 90 per cent levels were assessed using the incomplete gamma distribution function. The incomplete gamma probability distribution for weekly rainfall at Navsari region indicates that there is 90% probability of getting an assured rainfall of at least 1025.6 mm and 50% probability of getting 1523.6 mm. The results through analysis have been used for agricultural planning at Navsari region. Generally, the transplanting of paddy in Navsari region is carried out during 28th to 30th standard meteorological weeks (SMW) after monsoon onset, while the sugarcane planting is done during 42nd to 45th SMWs.

Key words – Rainfall probability, Markov Chain model, Incomplete Gamma distribution, Crop planning and weekly probability.

1. Introduction

The agricultural production potential of a given area is mainly dependant on rainfall, which varies both in space and time. To get the clear picture of the climate at a given place, normal of averages of long period data are taken into account. The average rainfall data gives simple understanding for a generalized application. As the distribution of rainfall varies over space and time, one need to analyze the data covering long periods and recorded at various locations to obtain reliable information. It is also natural to imagine that the total

agricultural production in any region depends not only on the total rainfall in a season, but also on its pattern of occurrence such as spells of rainy and dry days, etc. Thus, a model-based scientific study of the pattern of occurrence of weekly rainfall at regional level is therefore crucial for solving various water management problems and to assess the crop failure due to deficiency or excess of rainfall. Markov chain specify the state of each day as 'wet' or 'dry' and develop a relation between the state of the current day and the state of the preceding days. The order of the Markov chain is the number of preceding days taken into account. The yield of crops particularly under rain-fed condition depends on the rainfall pattern. Simple criteria related to sequential phenomena like dry and wet spells could be used for analyzing rainfall data to obtain specific information needed for crop planning and for carrying out agricultural operations (Reddy *et al.*, 2008). Senthilvelan *et al.* (2012) used Markov Chain model for probability of weekly rainfall in Orathanadu Taluk, Thanjavur District in Tamil Nadu. A week's period was considered as the optimum length of time. Markov Chain probability model has been recognized as a suitable model to explain the long term frequency behaviour of wet or dry spells. In this model, the conditional probability has been accepted as fully justified in the analysis of weekly rainfall data. Early withdrawal of rains also affects the yield due to severe moisture stress especially when the *kharif* crops are at critical growth stages of grain formation and grain development (Dixit *et al.*, 2005). The annual and seasonal analysis of rainfall will only give general idea about the rainfall pattern of the region, whereas the weekly analysis of rainfall will be of much use as far agricultural planning is concerned. Gabriel and Neumann (1962) analyzed the occurrence of rain at Tel Aviv, Israel, by fitting a two state, first-order Markov chain. The two states corresponded to 'rain' and 'no rain'. This accounts for the form of distribution of dry and wet spells. In particular, the distribution of the number of rainy days per week is obtained. Medhi (1976) studied wet and dry days in pre-monsoon and monsoon seasons during the period 1967-1970 month wise over Guwahati Airport and concluded that Markov chain of first order is adequate to represent each of the months. Fernandez *et al.* (1983) applied the same method to determine fine and bad weather days based on the sunshine hours at four cities. The fitting and the use of models for daily rainfall observation are discussed by (Stern and Coe., 1982, 1984). They found that the non-stationary Markov chains are fitted to the occurrence of rain, gamma distribution with parameters vary with time of year, are fitted to rainfall amount. They also concluded that numerical methods are used to derive results from these models that are important in agricultural planning. Srinivasareddy *et al.* (2008) used Markov Chain model probability of dry, wet weeks and statistical analysis of weekly rainfall for agricultural planning at Bangalore. Rajendram and Sivasamy (2005) applied Markov Chain model at 10, 20, 40 and 80 mm threshold levels to analyses probability of weekly rainfall and its agro climatic implications to paddy crop over Batticaloa, Sri Lanka. In Bangladesh, Sayedur Rahman (1999) used rainfall simulation model based on first-order Markov Chain to simulate the annual variation in rainfall amount. The objectives of the present study were to find out the weekly rainfall probabilities at different threshold levels at Navsari, Gujarat.

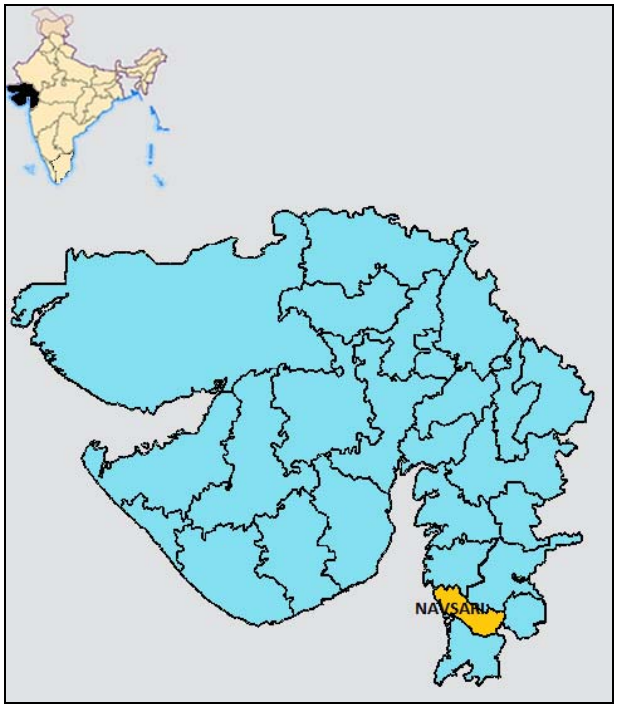

Fig. 1. Location map of Navsari

2. Data and methodology

Daily rainfall data recorded at the Meteorological Observatory of Navsari Agricultural University, Navsari (20°57' N latitude, 72°54' E longitude and 10 AMSL), Gujarat for a period of 34 years (1980 - 2013) have been used for the present study. Fig. 1 shows the location map of the Navsari region. Weekly rainfall values have been computed from daily values and were used for the present analysis. In this study data was distributed into two seasons, monsoon season (June to September) and Post-monsoon season (October to November). The dry and wet spell analysis was carried out using weekly rainfall based on Markov Chain Model considering threshold levels less than 20.0 mm, 40.0 mm, 60.0 mm, 80.0 mm and 100.0 mm rainfall in a week as a dry week and 20.0 mm, 40.0 mm, 60.0 mm, 80.0 mm and 100.0 mm or more as a wet week. Probabilities of rainfall occurrence at weekly

interval for 10, 25, 50, 75 and 90 per cent levels were assessed using the incomplete gamma distribution function. The different notations followed in this analysis are given below:

2.1. *Initial rainfall probability (%)(Wx)*

Initial probability indicates the minimum quantity of rainfall to be expected for a particular time series data.

Initial rainfall probability of getting greater than 20 mm rainfall during 'x' week = Wx

$$Wx = \frac{\text{No. of years with} > 20\,\text{mm rainfall during 'x' week}}{\text{Total no. of years}}$$

2.2. *Conditional rainfall probability (%)*

Conditional probability indicates the probability level at which a particular amount of rainfall is anticipated for a particular place over a specified time series data. Conditional probability is useful in predicting the receipt of particular quantity of rainfall for specific purposes based on historical data. Similarly conditional rainfall quantity can be fixed for various operations like weeding (10 mm), fertilizer application (15 mm) and plant protection (10 mm).

2.3. *Conditional rainfall probability (%) (W/Wx)*

Conditional rainfall probability (%) of getting >20 mm rainfall during next week also when there was rainfall of > 20 mm during this week (x)

$$W/Wx = \frac{\begin{array}{c}\text{No. of years where next week received} \\ > 20\,\text{mm rainfall when this week also} \\ \text{received} > 20\,\text{mm rainfall}\end{array}}{\begin{array}{c}\text{No. of years when this week (Wx)} \\ \text{received} > 20\,\text{mm rainfall}\end{array}} \times 100$$

2.4. *Conditional rainfall probability (%) (W/Dx)*

Conditional rainfall probability (W/Dx) of getting > 20 mm rainfall during next week when this week was dry, *i.e.*, the rainfall was < 20 mm

$$W/Wx = \frac{\begin{array}{c}\text{No. of years where next week received} \\ > 20\,\text{mm rainfall when this week (x)} \\ \text{received} < 20\,\text{mm rainfall}\end{array}}{\begin{array}{c}\text{No. of years when this week was dry} \\ \textit{i.e.}, < 20\,\text{mm rainfall was received}\end{array}} \times 100$$

where,

R = Rainfall,

W = Wet week,

W/Wx = Wet week followed by wet week and

W/Dx = Dry week followed by wet week

2.5. *Incomplete Gamma distribution*

The incomplete gamma distribution probability analysis was done in accordance with that of Victor (2000) and Kar (2002).

The general formula for the probability density function of the gamma distribution is,

$$f(x) = \frac{\left(\frac{x-\mu}{\beta}\right)^{\gamma-1} \exp\left(-\frac{x-\mu}{\beta}\right)}{\beta\,\Gamma(\gamma)} \qquad x \geq \mu; \gamma, \beta > 0$$

where, γ is the shape parameter, μ is the location parameter, β is the scale parameter and Γ is the Gamma function which has the formula

$$\Gamma(a) = \int_0^\infty t^{a-1} e^{-t}\, dt$$

The case where, μ = 0 and β = 1 is called the standard Gamma distribution and the equation for the same reduces to

$$f(x) = \frac{x^{\gamma-1} e^{-t}}{\Gamma(\gamma)} \qquad x \geq 0;\ \gamma > 0$$

Since the general form of probability functions can be expressed in terms of the standard distribution, all subsequent formulae in this section are given for the standard form of the function (Singh *at el.*, 2009).

3. Results and discussion

Analysis of weekly rainfall data of 34 years (1980-2013) indicated that the monsoon starts effectively from 22 Standard Meteorological Week abbreviated as SMW (28 May-3 June) and remains active up to 39 SMW (24-30 September) at Navsari. Therefore, mean length of rainy season was 18 weeks (126 days). The earliest and delayed week of onset of rainy season were 21 SMW (21-27 May) and 32 SMW (6-12 August), respectively. Similarly the earliest and delayed rainfall week of post-

TABLE 1

Weekly probability (%) analysis for 20.0 mm rainfall in Navsari region during monsoon season (SMW 22 to 39) and post-monsoon season (SMW 40 to 48)

S. No.	Week No.	Month	Date	Initial rainfall probability (%) (Wx)	Conditional rainfall probability (%) (W/Wx)	Conditional rainfall probability (%) (W/Dx)
			Monsoon season			
1.	22	May	28-03	8.8	0.0	35.5
2.	23	June	04-10	32.4	36.4	60.9
3.	24	June	11-17	47.1	62.5	44.4
4.	25	June	18-24	52.9	83.3	50.0
5.	26	June	25-01	67.6	87.0	72.7
6.	27	July	02-08	85.3	79.3	40.0
7.	28	July	09-15	73.5	92.0	44.4
8.	29	July	16-22	79.4	77.8	42.9
9.	30	July	23-29	70.6	83.3	70.0
10.	31	July	30-05	79.4	96.3	57.1
11.	32	August	06-12	88.2	66.7	50.0
12.	33	August	13-19	64.7	81.8	50.0
13.	34	August	20-26	70.6	66.7	60.0
14.	35	August	27-02	64.7	68.2	41.7
15.	36	September	03-09	61.8	66.7	46.2
16.	37	September	10-16	58.8	75.0	35.7
17.	38	September	17-23	58.8	45.0	28.6
18.	39	September	24-30	38.2	15.4	38.1
			Post-monsoon season			
19.	40	October	01-07	24.2	37.5	8.0
20.	41	October	08-14	15.2	0.0	3.6
21.	42	October	15-21	3.0	0.0	6.3
22.	43	October	22-28	6.1	0.0	6.5
23.	44	October	29-04	6.1	0.0	3.2
24.	45	November	05-11	3.0	0.0	0.0
25.	46	November	12-18	0.0	-	6.1
26.	47	November	19-25	6.1	0.0	0.0
27.	48	November	26-02	0.0	-	0.0

monsoon season were 40 SMW (1-7 October) and 48 SMW (26 November-2 December), respectively.

The results pertaining to initial and conditional probabilities of dry and wet weeks are presented in Tables 1 to 5) for monsoon and post-monsoon rainy season for 20.0, 40.0, 60.0, 80.0 and 100.0 mm rainfall for the 22 to 48 standard meteorological weeks (SMW). It may be noted from the data that the probability of occurrence of wet week (Wx) during monsoon season was highest during 29 to 32 weeks at 20.0 mm rainfall probability level. The analysis of initial rainfall probability (Wx) for 20.0 mm rainfall in monsoon season (22 to 39 SMW) indicated that the maximum probability is (88.2%) was during SMW 32 and minimum (8.8) during SMW 22. Similarly, at same rainfall probability level wet week

TABLE 2

Weekly probability (%) analysis for 40.0 mm rainfall in Navsari region during monsoon season (SMW 22 to 39) and post-monsoon season (SMW 40 to 48)

S. No.	Week No.	Month	Date	Initial rainfall probability (%) (Wx)	Conditional rainfall probability (%) (W/Wx)	Conditional rainfall probability (%) (W/Dx)
			Monsoon season			
1.	22	May	28-03	5.9	0.0	18.8
2.	23	June	04-10	17.6	33.3	42.9
3.	24	June	11-17	35.3	58.3	45.5
4.	25	June	18-24	50.0	76.5	35.3
5.	26	June	25-01	55.9	73.7	73.3
6.	27	July	02-08	73.5	64.0	55.6
7.	28	July	09-15	61.8	81.0	53.8
8.	29	July	16-22	70.6	75.0	40.0
9.	30	July	23-29	64.7	68.2	50.0
10.	31	July	30-05	61.8	71.4	69.2
11.	32	August	06-12	70.6	41.7	30.0
12.	33	August	13-19	38.2	46.2	42.9
13.	34	August	20-26	41.2	42.9	40.0
14.	35	August	27-02	41.2	71.4	40.0
15.	36	September	03-09	52.9	50.0	37.5
16.	37	September	10-16	44.1	60.0	31.6
17.	38	September	17-23	44.1	26.7	31.6
18.	39	September	24-30	29.4	0.0	20.8
			Post-monsoon season			
19.	40	October	01-07	15.2	20.0	3.6
20.	41	October	08-14	6.1	0.0	3.2
21.	42	October	15-21	3.0	0.0	6.3
22.	43	October	22-28	6.1	0.0	3.2
23.	44	October	29-04	3.0	0.0	3.1
24.	45	November	05-11	3.0	0.0	0.0
25.	46	November	12-18	0.0	-	0.0
26.	47	November	19-25	0.0	-	0.0
27.	48	November	26-02	0.0	-	0.0

followed by wet week (W/Wx) was highest during the SMWs 26, 28 and 31. While, for dry week followed by wet week (W/Dx) was more for SMWs 26, 31 and 34. Maximum conditional probability for (W/Wx) was 96.3% during SMW 31 and minimum (0.0%) during SMW 22. Maximum conditional probability (W/Dx) for dry week was 72.7% (SMW 5) and minimum 28.6% (SMW 17) (Table 1). In case of post-monsoon season (SMW 40 to 48) maximum initial rainfall probability for wet week (Wx) was 24.2% (SMW 40) and minimum of 0.0% (SMW 46 and 48). Maximum conditional rainfall probability for wet week followed by wet week (W/Wx) was 37.5% (SMW 40) and minimum of 0.0% (SMW 41 to 45, 47). Whereas, maximum rainfall probability for dry week followed by wet week (W/Dx) was 8.0 % (SMW 40) and minimum of 0.0 % (SMW 45, 47 and 48) (Table 1).

TABLE 3

Weekly probability (%) analysis for 60.0 mm rainfall in Navsari region during monsoon season (SMW 22 to 39) and post-monsoon season (SMW 40 to 48)

S. No.	Week No.	Month	Date	Initial rainfall probability (%) (Wx)	Conditional rainfall probability (%) (W/Wx)	Conditional rainfall probability (%) (W/Dx)
			Monsoon season			
1.	22	May	28-03	5.9	0.0	12.5
2.	23	June	04-10	11.8	50.0	26.7
3.	24	June	11-17	29.4	40.0	41.7
4.	25	June	18-24	41.2	64.3	35.0
5.	26	June	25-01	47.1	81.3	55.6
6.	27	July	02-08	67.6	56.5	45.5
7.	28	July	09-15	52.9	83.3	50.0
8.	29	July	16-22	67.6	69.6	45.5
9.	30	July	23-29	61.8	61.9	38.5
10.	31	July	30-05	52.9	61.1	37.5
11.	32	August	06-12	50.0	41.2	29.4
12.	33	August	13-19	35.3	33.3	31.8
13.	34	August	20-26	32.4	36.4	26.1
14.	35	August	27-02	29.4	80.0	25.0
15.	36	September	03-09	41.2	35.7	40.0
16.	37	September	10-16	38.2	46.2	23.8
17.	38	September	17-23	32.4	27.3	21.7
18.	39	September	24-30	23.5	0.0	11.5
			Post-monsoon season			
19.	40	October	01-07	9.1	0.0	6.7
20.	41	October	08-14	6.1	0.0	0.0
21.	42	October	15-21	0.0	-	0.0
22.	43	October	22-28	0.0	-	3.0
23.	44	October	29-04	3.0	0.0	0.0
24.	45	November	05-11	0.0	-	0.0
25.	46	November	12-18	0.0	-	0.0
26.	47	November	19-25	0.0	-	0.0
27.	48	November	26-02	0.0	-	0.0

The probability of occurrence of wet week (Wx) at 40.0 mm rainfall was highest during 27, 29 and 32 standard meteorological weeks. Initial rainfall probability (Wx) for 40.0 mm rainfall in monsoon season (week no. 22 to 39) maximum was 73.5% during SMW 27 and minimum was 5.9 during SMW 22. While at same probability level wet week followed by wet week (W/Wx) was highest during SMW 25, 26, 28, 29, 31 and 35. Similarly the probability of occurrence of dry week followed by wet week (W/Dx) was more in 26 and 31 SMW. Maximum conditional probability (W/Wx) for wet week was 81.0% during SMW 28 and minimum of 0.0% during SMW 22 and 18. Maximum conditional probability (W/Dx) for dry week was 73.3% during SMW 26 and minimum of 18.8% during SMW 22 (Table 2). In case of post-monsoon season (week no. 40 to 48) maximum initial

TABLE 4

Weekly probability (%) analysis for 80.0 mm rainfall in Navsari region during monsoon season (SMW 22 to 39) and post-monsoon season (SMW 40 to 48)

S. No.	Week No.	Month	Date	Initial rainfall probability (%) (Wx)	Conditional rainfall probability (%) (W/Wx)	Conditional rainfall probability (%) (W/Dx)
				Monsoon season		
1.	22	May	28-03	5.9	0.0	9.4
2.	23	June	04-10	8.8	33.3	29.0
3.	24	June	11-17	26.5	44.4	36.0
4.	25	June	18-24	35.3	50.0	36.4
5.	26	June	25-01	41.2	71.4	45.0
6.	27	July	02-08	55.9	57.9	40.0
7.	28	July	09-15	50.0	82.4	41.2
8.	29	July	16-22	61.8	52.4	46.2
9.	30	July	23-29	50.0	58.8	35.3
10.	31	July	30-05	47.1	43.8	38.9
11.	32	August	06-12	41.2	35.7	20.0
12.	33	August	13-19	29.4	20.0	16.7
13.	34	August	20-26	17.6	33.3	25.0
14.	35	August	27-02	23.5	75.0	19.2
15.	36	September	03-09	35.3	41.7	18.2
16.	37	September	10-16	29.4	40.0	12.5
17.	38	September	17-23	20.6	42.9	18.5
18.	39	September	24-30	23.5	0.0	11.5
				Post-monsoon season		
19.	40	October	01-07	9.1	0.0	6.7
20.	41	October	08-14	6.1	0.0	0.0
21.	42	October	15-21	0.0	-	0.0
22.	43	October	22-28	0.0	-	3.0
23.	44	October	29-04	3.0	0.0	0.0
24.	45	November	05-11	0.0	-	0.0
25.	46	November	12-18	0.0	-	0.0
26.	47	November	19-25	0.0	-	0.0
27.	48	November	26-02	0.0	-	0.0

rainfall probability for wet week (Wx) was 15.2 % during SMW 40 and minimum of 0.0% during SMW 46 and 48. Maximum conditional rainfall probability for wet week followed by wet week (W/Wx) was 20.0% during SMW 40 and minimum of 0.0% during SMW 41 to 45 and maximum conditional probability for dry week followed by wet week (W/Dx) was 6.3% during SMW 42 and minimum is 0.0% during SMW 45 to 48 (Table 2).

Probability of occurrence of wet week (Wx) at 60.0 mm rainfall was more in SMW 27, 29 and 30. Initial rainfall probability (Wx) for 60.0 mm rainfall in monsoon season (week no. 22 to 39) maximum was 67.6% during SMW 27 and minimum of 5.9 during SMW 22. Similarly, at same probability level the occurrence of wet week followed by wet week (W/Wx) was more in SMW 26, 28 and 35. The occurrence of dry week followed by wet

TABLE 5

Weekly probability (%) analysis for 100.0 mm rainfall in Navsari region during monsoon season (SMW 22 to 39) and post-monsoon season (SMW 40 to 48)

S. No.	Week No.	Month	Date	Initial rainfall probability (%) (Wx)	Conditional rainfall probability (%) (W/Wx)	Conditional rainfall probability (%) (W/Dx)
			Monsoon season			
1.	22	May	28-03	5.9	0.0	6.3
2.	23	June	04-10	5.9	50.0	21.9
3.	24	June	11-17	23.5	25.0	30.8
4.	25	June	18-24	29.4	40.0	33.3
5.	26	June	25-01	35.3	50.0	40.9
6.	27	July	02-08	44.1	46.7	47.4
7.	28	July	09-15	47.1	75.0	38.9
8.	29	July	16-22	55.9	52.6	46.7
9.	30	July	23-29	50.0	52.9	29.4
10.	31	July	30-05	41.2	42.9	15.0
11.	32	August	06-12	26.5	44.4	16.0
12.	33	August	13-19	23.5	0.0	19.2
13.	34	August	20-26	14.7	20.0	20.7
14.	35	August	27-02	20.6	85.7	11.1
15.	36	September	03-09	26.5	44.4	12.0
16.	37	September	10-16	20.6	28.6	14.8
17.	38	September	17-23	17.6	50.0	10.7
18.	39	September	24-30	17.6	0.0	7.1
			Post-monsoon season			
19.	40	October	01-07	6.1	0.0	6.5
20.	41	October	08-14	6.1	0.0	0.0
21.	42	October	15-21	0.0	-	0.0
22.	43	October	22-28	0.0	-	0.0
23.	44	October	29-04	0.0	-	0.0
24.	45	November	05-11	0.0	-	0.0
25.	46	November	12-18	0.0	-	0.0
26.	47	November	19-25	0.0	-	0.0
27.	48	November	26-02	0.0	-	0.0

week (W/Dx) was highest during 26 and 28 SMW. Maximum conditional probability (W/Wx) for wet week was 83.3% during SMW 28 and minimum of 0.0% during SMW 22 and 18. Maximum conditional rainfall probability (W/Dx) for dry week was 55.6% during SMW 26 and minimum of 11.5% during SMW 18 (Table 3). In case of post-monsoon season (week no. 40 to 48) maximum initial rainfall probability for wet week (Wx) was 9.1% during SMW 40 and minimum of 0.0% during SMW 42, 43, 45 to 48 and conditional rainfall probability for wet week followed by wet week (W/Wx) maximum and minimum was 0.0% during SMW 40, 41, 44 and maximum conditional rainfall probability for dry week followed by wet week (W/Dx) was 6.7% during SMW 40 and minimum of 0.0% during SMW 41, 42, 44 to 48 (Table 3).

The occurrence of probability of wet week (Wx) at 80.0 mm rainfall was highest during 27 and 29 SMW. Initial rainfall probability (Wx) for 80.0 mm rainfall in monsoon season (week no. 22 to 39) maximum was 61.8% during SMW 29 and minimum of 5.9 during SMW 22. At same probability level the probability of wet week followed by wet week (W/Wx) was more in SMW 26, 28 and 35. Probability of dry week followed by wet week (W/Dx) was more in SMW 26 and 29. Maximum conditional rainfall probability (W/Wx) was 82.4% during SMW 28 and minimum of 0.0% during SMW 22 and 18. Maximum conditional rainfall probability (W/Dx) for dry week was 46.2% during SMW 29 and minimum of 9.4% during SMW 22 (Table 4). In case of post-monsoon season (week no. 40 to 48) maximum initial rainfall probability for wet week (Wx) was 9.1% during SMW 40 and minimum of 0.0% during SMW 42, 43, 45 to 48 and maximum and minimum conditional rainfall probability for wet week followed by wet week (W/Wx) was 0.0% during SMW 40, 41, 44 and maximum conditional rainfall probability for dry week followed by wet week (W/Dx) was 6.7% during SMW 40 and minimum of 0.0% during SMW 41, 42, 44 to 48 (Table 4).

Probability of wet week (Wx) at 100.0 mm rainfall was high during 29 and 30 standard meteorological weeks. Initial rainfall probability (Wx) for 100.0 mm rainfall in monsoon season (week no. 22 to 39) maximum was 55.9% during SMW 29 and minimum of 5.9 during SMW 22, 23. Similarly at same probability levels occurrence of wet week followed by wet week (W/Wx) was more during 28 and 35 week no. and dry week followed by wet week (W/Dx) probability was more during 27 and 29 week no. Maximum conditional rainfall probability (W/Wx) for wet week was 85.7% during SMW 35 and minimum of 0.0% during SMW 22 and 18. Maximum conditional rainfall probability (W/Dx) for dry week was 47.4% during SMW 27 and minimum of 6.3% during SMW 22 (Table 5). In case of post-monsoon season (week no. 40 to 48) maximum initial rainfall probability for wet week (Wx) was 6.1% during SMW 40, 41 and minimum of 0.0% during SMW 42 to 48. Maximum and minimum conditional rainfall probability for wet week followed by wet week (W/Wx) was 0.0% during SMW 40, 41 and maximum conditional probability for dry week followed by wet week (W/Dx) was 6.5% during SMW 40 and minimum of 0.0% during SMW 41to 48 (Table 5).

The incomplete gamma probability distribution for weekly rainfall at Navsari region as given in Fig. 2 indicates that there was 90% probability of getting an assured rainfall of at least 1025.6 mm and 50% probability of getting 1523.6 mm. However the analysis indicates that at 75% and at 25% probability level the rainfall values were 1244.9 mm and 1841.3 mm respectively. There was

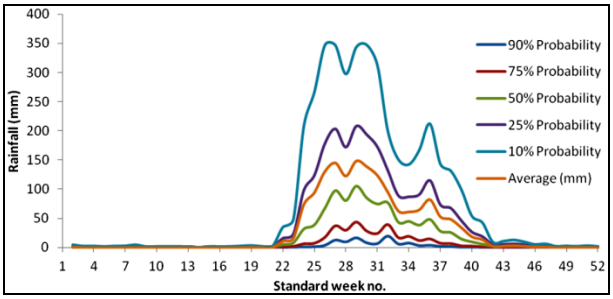

Fig. 2. Incomplete gamma distribution of weekly rainfall at different probability levels at Navsari region

10% probability of getting 2162.0 mm of assured rainfall during 34 years, which was maximum expected rainfall. Mean and expected weekly rainfall at different probability level (Fig. 2) showed that from 23rd SMW onwards the rainfall was recorded within the range of 16.5 mm to 18.9 mm per week and contributed up to 40th SMW. Fig. 2 indicates that 29th week has the highest rain, contributing 148.9 mm and 23rd week recorded the lowest rainfall of only 16.5 mm. At 50 per cent chances rainfall was assured in 24th week. A rainfall more than 50 mm per week occurs from 24th to 36th week at 50 per cent probability level.

4. Crop planning

The study of weekly rainfall data cannot be neglected since this kind of study provides useful information in crop planning. Modeling the weekly rainfall data is very important especially for crop planning to prepare schedules of farm operations in irrigation of the crops. Besides that, it can also be used for the predication of water storage in supplying water. Therefore, this study focuses on indentifying the most appropriate probability model to describe the distribution of weekly wet and dry spells in Navsari region.

Paddy and Sugarcane are the major crops in the region and have growing period of 120-150 and 360-420 days, respectively. The crop planning of this area is done at 50 percent probability level so that early sowing of paddy crop for nursery can be done in 24th and 25th week for better germination. Therefore, germination will be difficult after these weeks. The transplanting of paddy should be completed in the last month of July. The 31st, 34th and 39th weeks would be tillering, panicle initiation and maturity respectively. The harvesting of paddy should be completed in October. Another major crop of the region is Sugarcane, which is about 12 to 14 months (360-420 days) duration. The sowing of sugarcane should be completed in the October-November (autumn planting) and January-February (spring planting). For autumn planting 2nd, 8th and 51st weeks would be tillering, yield

formation and ripening respectively. For spring planting 18th, 27th and 2nd weeks would be tillering, yield formation and ripening respectively. During the years with delay in onset of monsoon, the length of growing season may start as late as 27th week (2 July-8 July) in the region. Under normal condition, it starts by 24th week (11 June-17 June). During the years with early withdrawal of southwest monsoon, the length growing season ends by 40th week (1 October-7 October). During some of the years, the post-monsoon rain may extend the length of growing season upto 50th to 52nd week (10 December-16 December to 24 December-31 December).

5. Conclusion

Markov Chain model has been fitted to weekly rainfall data to obtain sequences of dry and wet spells during the monsoon season. Rainfall is the critical factor in farm management. The Markov Chain Model, the rain prediction model based on data for 34 years (1980-2013). Month wise, July is more rain producing month than others months produces 20-30% rain of whole year while week wise 24th to 36th weeks received more rainfall then other weeks. The Markov Chain Model concludes that there is decrease in dry weeks than wet weeks. These results a prediction of slow increase of rains may be forecasted in coming weather situations. Due to long dry spells, dryness was found which has a serious impact on water availability, socio economic factors, viral diseases and environmental problems for entire place. It is required to create the means for the storage of rainfall that can be utilized on the hard time to meet the shortage of water.

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