631.15 : 551.577.3 (540.29)

DRY AND WET SPELL PROBABILITY BY MARKOV CHAIN MODEL FOR AGRICULTURAL PLANNING AT PARBHANI

1. India's economy is mainly dependent on agriculture, which is based on monsoon rainfall and its distribution. Fluctuation in rainfall directly influences the growth, development and yield of crops. India ranks first among the countries that practice rainfed agriculture both in terms of extent (86 Mha) and value of production (Sharma and Singh, 2010). For successful agricultural management and planning of soil water conservation measures, information about occurrence of dry and wet periods along with onset and withdrawal of rainy season is important. Panigrahi and Panda (2002) and Kar (2003) applied Markov Chain method for calculating initial and conditional probability of dry and wet spells of different duration for various climatic situations and have evaluated its practical importance in crop planning. Researchers (Sarker *et al*., 1982; Pandarinath, 1991; Thiyagaraj *et al*., 1995; Chattopadhyay and Ganesan, 1995; Banik *et al.*, 2002; Barron *et al*., 2003 and Deni *et al*., 2010) have used Markov chain model to study the probability of dry and wet spell analysis in terms of the shortest period like week and also demonstrated its practical utility in agricultural planning. In the present study an attempt has been made to analyze the probable week of onset and withdrawal of monsoon, initial and conditional probability of dry and wet spells and also the probability of 2 and 3 consecutive dry and wet spell weeks using Markov chain model for agricultural planning in Parbhani district of Maharashtra.

2. Daily rainfall data collected from Department of Agricultural Meteorology, Vasantrao Naik Marathwada Agricultural University (VNMKV), Parbhani, for a period of 42 years (1971-2012) were used for the present study. Weekly rainfall values have been computed from daily values and were used for the present analysis. Onset and withdrawal of rainy season was computed from weekly rainfall data by forward and backward accumulation methods respectively. Seventy five millimetres of rainfall accumulation has been considered as the onset time for the growing season of dry seeded crops and land preparation (Babu and Lakshminarayana, 1997; Panigrahi and Panda, 2002). The withdrawal of rainy season was determined by backward accumulation of rainfall (48 + 47 + 46 + … + 30 weeks) data. Twenty millimetres of rainfall accumulation was chosen for the end of rainy season, which is sufficient for ploughing of fields after harvesting the crops (Babu and Lakshminarayana, 1997). The dry and wet spell analysis was carried out using weekly rainfall based on Markov Chain Model considering less than 20 mm rainfall in a week as a dry week and 20 mm or more as a wet week (Pandharinath, 1991).

TABLE 1

Rainfall distribution in the Parbhani region over different seasons and probability of onset and withdrawal of effective monsoon (data of 42 years for the period 1971-2012)

Seasons	Average rainfall (mm)	Percentage of total rainfall	SD	Coefficient of variation (%)
Pre-monsoon (March-May)	34.4	3.7	32.1	93.5
Monsoon (June-September)	776.5	83.6	282.3	36.3
Post-monsoon (October-December)	105.6	11.4	87.2	82.7
Winter (January-February)	11.9	1.3	17.8	150
Characterisation of rainy season at Parbhani				
Mean week of onset of rainy season	24 - SMW (44.20)			
Earliest week of onset of rainy season	21 - SMW (4.65)			
Delayed week of onset of rainy season	27 - SMW (95.30)			
Mean week of withdrawal of rainy season	43 - SMW (48.80)			
Earliest week of withdrawal of rainy season	39 - SMW (9.31)			
Delayed week of withdrawal of rainy season	48 - SMW (93.00)			
Mean length of rainy season	20 weeks			

SD = Standard deviation, () Probability of onset (Forward accumulation from 21st week) and withdrawal of effective monsoon (Backward accumulation from 48th week)

TABLE 2

Probabilities dry and wet week spells of rainfall at the study site, Parbhani region

SMW	Initial probabilities (%)		Conditional probabilities (%)				Consecutive dry week probabilities (%)		Consecutive wet week probabilities (%)	
	P_D	P_W	P_{DD}	P_{WD}	P_{WW}	P_{DW}	P_{2D}	P_{3D}	P_{2W}	P_{3W}
21	90.5	9.5	89.7	10.3	0.0	100.0	78.2	51.4	4.8	2.0
22	83.4	16.6	86.4	13.6	50.0	50.0	54.8	24.4	7.1	5.2
23	64.3	35.7	65.7	34.3	42.8	57.2	28.6	10.7	26.2	15.1
24	38.1	61.9	44.5	55.5	73.4	26.6	14.3	5.0	35.7	17.1
25	40.5	59.5	37.5	62.5	57.7	42.3	14.3	6.0	28.6	14.9
26	45.2	54.8	35.3	64.7	48.0	52.0	19.0	10.0	28.6	19.9
27	45.2	54.8	42.1	57.9	52.2	47.8	23.8	16.8	38.1	21.4
28	40.5	59.5	52.6	47.4	69.6	30.4	28.6	12.4	33.3	28.1
29	54.8	45.2	70.6	29.4	56.0	44.0	23.8	7.3	38.1	23.6
30	30.9	69.1	43.5	56.5	84.2	15.8	9.5	3.8	42.9	25.4
31	35.7	64.3	30.8	69.2	62.1	37.9	14.3	5.9	38.1	21.3
32	40.5	59.5	40.0	60.0	59.2	40.8	16.7	5.6	33.3	22.2
33	42.8	57.2	41.2	58.8	56.0	44.0	14.3	6.1	38.2	24.5
34	33.4	66.6	33.4	66.6	66.7	33.3	14.3	6.2	42.8	29.6
35	38.1	61.9	42.8	57.2	64.3	35.7	16.6	10.0	42.8	19.1
36	35.7	64.3	43.7	56.3	69.2	30.8	21.4	11.6	28.6	17.5
37	57.1	42.9	60.0	40.0	44.5	55.5	30.9	18.6	26.3	15.5
38	47.6	52.4	54.2	45.8	61.2	38.8	28.6	23.1	31.0	16.2
39	50.0	50	60.0	40.0	59.1	40.9	40.5	34.5	26.2	10.5
40	64.3	35.7	80.9	19.1	52.4	47.6	54.8	39.4	14.3	4.3
41	76.2	23.8	85.2	14.8	40.0	60.0	54.8	49.3	7.1	1.8
42	71.4	28.6	71.9	28.1	30.0	70.0	64.3	57.1	7.2	1.2
43	85.7	14.3	90.0	10.0	25.0	75.0	76.2	68.0	2.4	0.0
44	88.1	11.9	88.9	11.1	16.7	83.3	78.6	72.4	0.0	0.0
45	90.5	9.5	89.2	10.8	0.0	100.0	83.4	72.7	0.0	0.0
46	92.8	7.2	92.1	7.9	0.0	100.0	80.9	78.7	0.0	0.0
47	88.1	11.9	87.2	12.8	0.0	100.0	85.7	83.6	4.8	1.6
48	92.8	7.2	97.3	2.7	40.0	60.0	90.5	90.5	2.4	1.2
49	95.2	4.8	97.5	2.5	33.4	66.6	95.2	92.9	2.4	0.0
50	97.6	2.4	100.0	0.0	50.0	50.0	95.3	90.6	0.0	0.0
51	97.6	2.4	97.6	2.4	0.0	100.0	92.8	90.4	0.0	0.0
52	95.2	4.8	95.1	4.9	0.0	100.0	92.9	88.3	0.0	0.0

3. The results of forward and backward accumulation of weekly rainfall for onset and withdrawal of effective monsoon (Table 1) indicated that the monsoon started effectively from the 24th SMW (11-17 June) and remained active up to the 43rd SMW (22-28 October). Therefore, mean length of rainy season was found to

be 20 weeks (140 days). The earliest and delayed onset of rainy season was 21th SMW (21-27 May) and 27th SMW (2-8 July), respectively. Similarly, the earliest and delayed week of cessation of rainy season was 39th SMW (24-30 September) and 48th SMW (26 November - 2 December), respectively. The results of initial and conditional probabilities of dry and wet weeks and consecutive dry and wet weeks are presented in Table 2 for standard meteorological weeks (Monsoon and Post-monsoon season only). It is clear from results that, probability of occurrence of wet week is more than 35% during 23-24th SMW (4 June-17 June) and average weekly rainfall ranges from 27.4 to 41.9 mm, this rain can be utilized for summer ploughing and initial seed bed preparations. The mean onset of rainy season was found to be 24th SMW. So, during 24th SMW (11 June-17 June), the sowing operations can be taken up since, the probability of wet week is more than 50% and average weekly rainfall is 41.9 mm. Sowing operations taken at 24th SMW helps for good germination of seeds and helps in avoiding moisture stress for germination period during 25-28 SMW. In the event of delayed start of rainy season, the sowing operations can be taken up latest by 27th SMW (2 July-8 July) and further delay in sowing may cause very low productivity and crop failure. Since, mean length of rainy season was observed to be 20 weeks (140 days), during *kharif*, short duration crops of groundnut, pigeon pea, maize, sorghum, green gram, soybean, sunflower, field bean, cowpea and other low water required crops which have high return value can be taken up. Another advantage of growing short duration cereals, pulses and oilseeds in first fortnight of June is that these can be harvested by the end of September (39th SMW) and short duration *rabi*crops can be sown during 40 - 43 SMW (1-28 October). During *kharif* season *in situ* water conservation measures (*viz.*, contour cultivation, conservation furrows, broad bed and furrow system etc.) to be taken up for improving moisture regime in soils. Since, winter rainfall is uncertain and erratic than SW monsoon also it contribute only 11.4% of total rainfall. Therefore growing of high value *rabi* crops without supplementary irrigation would be very high risky during *rabi* season. During SW monsoon season, the probability of dry week (P_D) being more than 50% were observed during 29th, 37th and 40th to 43rd SMW and also chance of dry week preceded by another dry week (P_{DD}) were more than 50% during 28th, 29th and 37th to 43rd SMW. Therefore during those dry weeks especially at the end of main rainy season, supplementary irrigation and moisture conservation practice such as mulching need to be undertaken. The significant contribution of weekly rainfall, *i.e.*, 42.2% of total annual rainfall during 30-36 SMW and high consecutive wet week probability during 30-35 SMW, indicate for potential scope of harvesting excess runoff water by constructing site specific structures such as farm pond, bore well recharging structure, check dams, *nala* bunds, gully plugging etc. Also the excess water could be taken out from the fields safely through community drainage channels and stored in suitable low-cost water harvesting structures.

4. During rainy season probability of dry week (P_D) being more than 50% was observed during 29th, 37th and 40th to 43rd SMW and also chance of dry week preceded by another dry week (P_{DD}) was more than 50% during 28th, 29th and 37th to 43rd SMW. Therefore during those dry weeks especially at the end of SW monsoon season, supplementary irrigation and moisture conservation practice need to be undertaken. The significant contribution of weekly rainfall, *i.e.*, 42.2% of total annual rainfall during 30-36 SMW and high consecutive wet week probability during 30-35 SMW, hints for potential scope of harvesting excess runoff water for future supplemental irrigations and also drives attention towards soil erosion measures to be taken up for soil erosion control. This study revealed that the last 14 weeks of the year, *i.e.*, from 39th to 52nd SMW, may remain under stress on an average, as there were 78% chances of occurrence of two consecutive dry weeks. The corresponding value for three consecutive dry weeks during the period was 72 %.

5. The authors would like to thank Department of Agricultural Meteorology, Vasantrao Naik Marathwada Agricultural University (VNMKV), Parbhanifor facilitating the study.

The contents and views expressed in this letter are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

References

Babu, P. N. and Lakshminarayana, P., 1997, "Rainfall analysis of a dry land watershed-Polkepad: A case study", *J. Indian Water Res. Society*, **17**, 34-38.

Banik, P., Mandal, A. and Sayedur, Rahman M., 2002, "Markov chain analysis of weekly rainfall data in determining drought-proneness", *Discret Dyn. Nat. Soc.*, **7**, 231-239.

Barron, J., Rockstrom, J., Gichuki, F. and Hatibu N., 2003, "Dry spell analysis and maize yields for two semi-arid locations in east Africa", *Agric. Forest Meteorol.*, **117**, 23-37.

Chattopadadhyay, N. and Ganesan, G. S., 1995, "Probability studies of rainfall and crop production in coastal Tamil Nadu", *Mausam*, **46**, 3, 263-274.

Deni, S. M., Suhaila, J., Wan Zin, W. Z. and Jemain, A. A., 2010, "Spatial trends of dry spells over Peninsular Malaysia during monsoon seasons", *Theor. Appl. Climatol.*, **99**, 3-4, 357-371.

Kar, G., 2003, "Initial and conditional probabilities of rainfall and wet and dry spells for red and laterite zone of West Bengal using Markov Chain model", *Indian J. Soil Cons.*, **31**, 3, 287-290.

Pandarinath, N., 1991, "Markov chain model probability of dry and wet weeks during monsoon periods over Andhra Pradesh", *Mausam*, **42**, 4, 393-400.

Panigrahi, B. and Panda, S. N., 2002, "Dry spell probability by Markov Chain model and its application to crop planning", *Indian J. Soil Cons.*, **30**, 95-100.

Sarker, R. P., Biswas, B. C. and Khambete, N. V., 1982, "Probability analysis of short period of rainfall in dry farming tract in India", *Mausam*, **33**, 3, 269-284.

Sharma, M. A. and Singh, J. B., 2010, "Use of probability distribution in rainfall analysis", *New York Science J.*, **3**, 9, 40-49.

Thiyagarajan, M. R. and Ramaraj, 1995, "A Markov chain model for daily rainfall occurrences at east Thanjavur district", *Mausam*, **46**, 4, 383-388.

P. S. PAWAR,
A.U. WAIKAR and
U. M. KHODKE

College of Agricultural Engineering and Technology, Vasantrao Naik Marathwada Agricultural University, Parbhani – 431 402 (M.S.), India

(*Received 9 February 2016, Accepted 5 April 2019*)
email: pspawar71@gmail.com