Mausam, (1984), **35**, 1, 99-102

551.577.31 : 519.2

Spell distribution and weather cycle at Chandigarh*

Y. AGNIHOTRI, R. C. BANSAL and PRAHLAD SINGH
Central Soil & Water Conservation Research & Training Institute, Research Centre, Chandigarh

(Received 23 June 1982)

सार – नम/शुष्क दौर एवं मौसम चक्र की प्रागुक्ति के एक प्रयास में चंडीगढ़ के दैनिक वर्षा के आंकड़ों के लिए मारकोव चेन निदर्श का समंजन किया गया है । नम/शुष्क दिन के बाद अगला दिन नम होने की सप्रतिबंध प्रायिकता की गणना की गई है । निदर्श की सहायता से नम और शुष्क, दौरों की प्रत्याशित बारंबारताएं एवं मौसम चक्र भी ज्ञात किए गए हैं । χ^2 परीक्षण के आधार पर किए अध्ययनों से यह स्पष्ट है कि प्रत्याशित बारंबारताएं, प्रेक्षित बारंबारताओं के काफी निकट है ।

ABSTRACT. In an attempt to predict wet/dry spell and weather cycle, Markov chain model was fitted to the daily rainfall data (1958 to 1980) of Chandigarh. Conditional probabilities for occurrence of wet day preceded by wet/dry day were calculated and the expected frequencies of wet and dry spell and the weather cycle have been worked out with the help of the model. The study on the basis of χ^2 test has revealed the expected frequencies to fall in agreement with the observed ones.

1. Introduction

Knowledge of wet and dry spells and weather cycle in advance is very useful for crop planning. Gabriel and Neuman (1962) & Bhargava *et al.* (1977) fitted daily rainfall data to a Markov chain model which predicts the probability of occurrence of wet and dry spells. Basu (1971) also fitted a Markov chain probability model to the daily rainfall data at Calcutta and found that the wet spell and weather cycle obey geometric distribution. Victor and Sastry (1979) fitted the Markov chain model to daily rainfall data of the monsoon months in Delhi region. They have computed conditional probabilities, and length of dry days with particular reference to development stages of Bajra crop. An attempt has been made in the present study to fit a Markov chain model to daily rainfall data of Chandigarh. Predictability of dry and wet spells and dry-wet and wet-dry cycles has been tested by comparing observed and expected frequencies through application of χ^2 test.

2. Method and materials

Markov chain model in terms of rainfall occurrence has been defined by Gabriel and Neumann (1962) as the model in which the probability of rainfall on any day depends only on whether the previous day was wet or dry. The probability of rainfall in this model has been assumed to be independent on further preceding days. Adequacy of the model was tested through χ^2-tests as suggested by Anderson and Goodman (1957).

Parameters of the two conditional probabilities required to describe the model are given as :

$$p_1 = P_r \text{ (wet day given the previous day wet)} \quad (1)$$

$$p_0 = P_r \text{ (wet day given the previous day dry)} \quad (2)$$

A wet spell of length m is defined as a sequence of m wet days preceded and followed by a dry day. A dry spell is defined in the similar way. A weather cycle is defined as the combination of a wet spell with immediate successive dry spell (wet-dry cycle) or a dry spell with immediate successive wet spell (dry-wet cycle).

Probability of a wet spell of length n is $(1-p_1)\, p_1^{n-1}$ (3)

and that of a dry spell of length m is $p_0(1-p_0)^{m-1}$ (4)

According to the model described above the lengths of dry and wet spell, would be independent, so distribution of the length of the weather cycle is :

$$f(n, p_0, p_1) = p_0 (1-p_1) \frac{(1-p_0)^{n-1} - p_1^{n-1}}{1-p_0-p_1} \quad (5)$$

where n is length of cycle (days).

Departure of the expected from observed frequencies of the wet/dry spell and the weather cycle was tested for its significance by χ^2 test (Goulden 1952).

*Authorised for publication by the Director, as contribution No. 160-70/82 of the Central Soil and Water Conservation Research & Training Institute, Dehradun (U.P.).

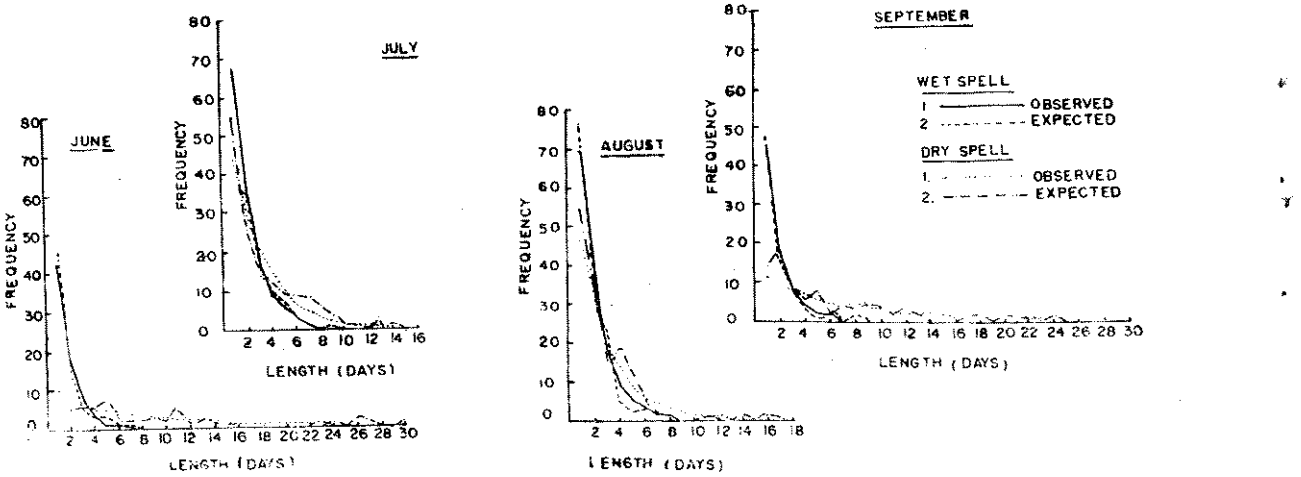

Fig. 1. Expected and observed frequencies of dry/wet spell (June to September)

The daily rainfall data recorded at the Central Soil & Water Conservation Institute, Research Centre (Research Farm, Mansa Devi) from 1958-1980 was used for the above analysis. The following criteria were fixed in the analysis for classification of a wet day, wet/dry spell, and weather cycle :

(*i*) A day was defined to be a wet day if it received rainfall more than or equal to 2.5 mm.

(*ii*) A wet spell was included in a month if any day of this particular spell falls within that month, no matter if the wet spell does not end in that month.

(*iii*) A dry spell is included in a month only if the immediately following wet spell (as defined in (*ii*) is included in that particular month. In case a month ends with a dry day, the dry spell including that dry day should be accounted in the following month.

(*iv*) A wet-dry cycle or dry-wet cycle has been included in a month if any part of the wet spell falls in that month.

3. Results and discussion

Calculated value of χ^2 for testing appropriation of the 1st order Markov chain model against independence and 2nd order Markov chain model are given in Table 1. The test for independence strongly suggests that the probability of occurrence of rainfall on any day is dependent on the fact whether or not the previous day is a wet day, as the calculated values of χ^2 are much greater than the tabulated value of χ^2 at 5% level. The χ^2 statistic at 5% level for the test of first *versus* second order of the model is not significant for any of the four months. This indicates that the Markov chain model of order 1 would be as effective as the model of order 2, for working out expected frequencies of wet and dry spells and the weather cycle.

Conditional probabilities for occurrence of wet day preceded by wet and dry day respectively has been estimated for the months June to September. The same are shown in Table 2.

It is indicated from the Table 2 that during July and August conditional probability for occurrence of wet day after a wet day is almost 0.5 and of wet day after a dry day is 0.3.

Expected and observed frequency of dry and wet spell of various lengths during the rainy months is shown in Table 3.

It is seen from Table 3 that expected frequency of wet and dry spell during all the months fit well with the observed values since calculated value of χ^2 is non-significant at 5% level during all the four months.

Expected duration of wet spell is seen upto 6 days in the months of June, September and 7 and 8 days in the months of July and August respectively. However, the table shows that a wet spell of 14 days occurred once during August. Expected maximum length of dry spell is seen to be 23, 13, 12 and 22 during the months from June to September respectively. It is interesting to note from the table that a dry spell of 30 days during the months of June and September was observed once.

Observed and expected frequency of wet and dry spells during June to September is shown in the Fig. 1. Table 4 shows observed and expected frequency of dry-wet and wet-dry cycle along with the calculated value of χ^2. It is seen from Table 4 that dry-wet/wet-dry cycle of longer durations occur in June and September. This is probably because of longer frequency of dry spell during the two months. χ^2-test indicates that expected weather cycle tallies well with the observed frequency during the 4 months. However, expected wet-dry cycle during June is seen to depart from the observed frequency.

4. Conclusion

The observed frequency of weather cycle of various durations and dry/wet spells are seen to follow the geometrical distribution as proposed by Gabriel and Neumann (1962).

χ^2-test for appropriation of 1st order Markov chain model against independence suggest that the probability of occurrence of rainfall on any day is dependent on the fact whether or not the previous day was wet.

TABLE 1

χ^2 test of significance

Test for	Calculated χ^2 statistic				χ^2 (tab, 5%)
	Jun	Jul	Aug	Sep	
Independence *vs* I order Markov chain (1df)	71.2**	106.4**	106.6**	83.3**	3.84
1st order *vs* 2n dorder Markov chain (2 df)	4.44	1.30	1.05	1.05	5.99

**Significant at 1% levels.

TABLE 2

Conditional probabilities for occurrence of a wet day for various rainy months

	Preceding day	Conditional probability of actual wet day
Jun	Wet	.4310
	Dry	.1307
Jul	Wet	.5088
	Dry	.3232
Aug	Wet	.5103
	Dry	.3357
Sep	Wet	.4074
	Dry	.1405

TABLE 3

Expected and observed frequency of dry and wet spell of various lengths

Length of spell (days)	Wet spell								Dry spell							
	June		Jul		Aug		Sep		Jun		Jul		Aug		Sep	
	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O
1	42	45	68	68	69	77	45	47	10	17	45	54	47	54	11	13
2	18	14	35	33	35	28	18	16	8	5	30	26	32	34	9	17
3	8	6	18	16	18	22	8	8	7	6	21	15	21	14	8	8
4	3	3	9	10	9	6	3	2	6	5	14	9	14	18	7	6
5	1	3	5	7	5	2	1	—	6	8	10	8	9	10	6	7
6	1	1	3	3	3	3	1	2	5	3	6	5	6	4	5	2
7	—	1	1	1	1	2	—	—	4	3	4	8	4	3	4	4
8	—	—	—	—	1	—	—	1	4	3	3	5	3	2	4	3
9	—	—	—	1	—	—	—	—	3	4	2	4	2	—	3	4
10	—	—	—	—	—	—	—	—	3	2	1	1	1	—	3	2
11	—	—	—	—	—	—	—	—	2	5	1	1	1	1	2	1
12	—	—	—	—	—	—	—	—	2	1	1	—	1	—	2	2
13	—	—	—	—	—	—	—	—	2	2	1	2	—	—	2	1
14	—	—	—	1	—	1	—	—	2	1	—	—	—	—	2	—
15	—	—	—	—	—	—	—	—	1	1	—	1	—	—	1	1
16	—	—	—	—	—	—	—	—	1	—	—	—	—	1	1	1
17	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—
18	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	1
19	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	1
20	—	—	—	—	—	—	—	—	1	1	—	—	—	—	1	—
21	—	—	—	—	—	—	—	—	1	1	—	—	—	—	1	1
22	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—
23	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—
25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—
27	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—
28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
Total	73	73	139	139	141	141	76	76	73	73	139	139	141	141	76	76
χ^2 cal	3.4		0.85		4.61		0.31		9.4		11.4		6.9		11.4	
D.F.	2		3		3		2		6		6		5		6	
χ^2 tab (5%)	5.99		7.82		7.82		5.99		12.59		12.59		11.07		12.59	

E : Expected frequency, O : Observed frequency.

TABLE 4

Observed and expected frequency of weather cycle

Length of cycle (days)	June			Jul			Aug			Sep		
	Obs. cycle		Exp. cycle	Obs. cycle		Exp. cycle	Obs. cycle		Exp. cycle	Obs. cycle.		Exp. cycle
	D.W.	W.D.		D.W.	W.D.		D.W.	W.D.		D.W.	W.D.	
2	12	12	6	24	32	22	26	27	23	8	7	6
3	5	2	7	27	26	26	28	26	27	12	10	8
4	7	15	7	22	22	23	29	16	24	8	10	7
5	2	5	7	18	14	19	13	25	19	6	6	7
6	10	3	6	9	13	14	19	9	15	8	4	6
7	7	8	6	9	9	10	9	12	10	3	6	5
8	4	6	5	5	7	7	8	6	7	5	4	5
9	1	5	4	6	4	5	2	7	5	2	2	4
10	6	5	4	6	3	4	1	2	4	4	3	4
11	0	4	3	2	4	3	1	2	2	2	5	3
12	5	2	3	4	1	2	1	—	2	2	—	3
13	1	1	3	1	1	1	2	1	1	3	1	2
14	2	2	2	1	1	1	—	2	1	—	2	2
15	2	2	2	1	—	—	—	—	1	—	1	1
16	3	1	2	1	—	—	2	—	—	2	1	1
17	1	—	2	1	—	—	—	2	—	2	—	1
18	—	—	1	—	—	—	—	—	—	—	3	1
19	—	—	1	—	—	—	—	1	—	1	—	1
20	—	—	1	—	—	—	—	1	—	1	1	1
21	1	1	1	—	—	—	—	1	—	—	—	1
22	1	—	1	—	—	—	—	1	—	1	1	1
23	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—	—	—	—	—	—
25	1	—	—	—	—	—	—	—	—	—	—	—
26	—	—	—	—	—	—	—	—	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	—	—
28	2	—	—	—	—	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	—	—	1	—
30	1	—	—	—	—	—	—	—	—	—	2	—
Total	74	74	74	137	137	137	141	141	141	70	70	70
χ^2 cal	7.94		18.09*	5.84		6.14	10.72		9.24	5.81		3·12
D.F.	8		6	7		7	7		7	7		7
χ^2 tab (5%)	15.5		12.59	14.07		14.07	14.07		14.07	14.07		14·07

*Significant at 5% level.

χ^2-statistic for 1st order *versus* second order Markov-chain model is not significant during the 4 months revealing the 1st order model to be as effective as 2nd order model for workingout spells.

Conditional probabilities for occurrence of a wet day after a wet day is 0.5 during July and August while during June and September it is 0.4. The conditional probabilities for occurrence of a wet day after a dry day is 0.3 during July and August whereas it is low as 0.1 during June and September.

Acknowledgement

The authors are thankful to Shri Ram Murti, T.A. (Stat.) for assisting analysis of data.

References

Anderson, T. W. and Goodman, L. A., 1957, *Ann. Math. Stat.*, **28**, pp. 89-110.

Basu, A. N., 1971, *Indian J. Met. Geophys.*, **22**, pp. 67-74.

Bhargava, P. N., Narain, P., Singh, D. and Asha Saxena, 1977, Monograph Instt. Agr. Res. Stat., New Delhi, pp. 76-82.

Gabriel, K. R. and Neumann, J., 1962, *Quart. J. R. met. Soc.*, **88**, pp. 90-95.

Goulden, Cyril H., 1952, *Methods of Statistical Analysis*, Asia Publishing House, pp. 353-368.

Victor, U. S. and Sastry, P.S.N., 1979, *Mausam*, **30**, 4, pp. 479-484.