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Weekly Analysis of Rainfall at Bellary, Karnataka

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Abstract

The success or failure of crops particularly under rainfed conditions is closely linked with the rainfall patterns. Therefore, a prior knowledge on sequences of dry and wet periods is essential for agricultural planning. It is essential to know the most probable dates of onset and withdrawal of monsoon to plan agricultural operations and corrective measures to be taken up during dry periods to avoid any kind of moisture stress. In this paper, an effort was made to analyze the weekly rainfall data to assess the occurrence of dry spells using Markov chain model and to suggest effective onset and withdrawal of rainy season. For the present study, the rainfall records of Central Soil and Water Conservation Research and Training Institute (CSWCR & TI), a research center Bellary for the past 31 years (1976—2006) were used. The results revealed that the occurrence of dry week was high throughout all standard meteorological weeks and ranged more than 70% during all weeks except smw (Standard Meteorological Week) 22—23 and 38—41. The probability of 2 and 3 consecutive dry weeks during rainy season (smw 20—48) ranged from 25.8 to 96.8% and 18.2 to 90.5% respectively. Weekly rainfall data indicated that the monsoon starts effectively from smw 27 (2—8 July) and remains active up to smw 43 (22—28 October). Therefore, the mean length of rainy season was found to be 16 weeks (112 days). The weekly mean rainfall during the last 31 years ranged between 0.00 mm (smw 4) to 33.92 mm (smw 38).

Key words : Markov chain, Dry spells, Wet spells, Rainfall analysis.

Crop production is mainly dependent on water availability. Rainfall variability influences the water availability. Out of all climatic parameters, rainfall has many facets. In general, annual rainfall or the extent of its deviation from normal is taken as the main independent variable for different analyses such as prediction of drought and crop yield. However, it is just not the total quantity of rainfall but its distribution which is more important (1). Hence, scientific analysis is important to have a prior knowledge on probabilities of dry and wet spell occurrences and probable date of onset and withdrawal of effective monsoon during growing season, which may prove useful to farmers for improving productivity and cropping intensity and in turn their economic returns. The dry and wet spell analysis will help in selection of cropping patterns, varieties to withstand dry spells and to plan suitable soil and water conservation measures/structures. The time period between onset and withdrawal of rainy season will give an idea of length of growing season and analysis of rainfall on weekly basis instead of monthly or seasonally, will be an important factor to assess the distribution pattern of rainfall.

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Methods

For the present study, the daily rainfall records were taken from the agro-meteorological observatory located at Central Soil and Water Conservation Research and Training Institute (CSWCR & TI, a soil and water conservation research institute for the tract of black cotton soils of peninsular India, located at Bellary (lat. 15°19′ N, long. 76°51′ E and Alt. 445 m amsl), Karnataka for a period of 31 years (1976—2006). Weekly rainfall values were computed from daily values and were used for the present analysis.

Table 1. Initial and conditional probabilities of rainfall at Bellary.

SMW	Initial probabilities (%) P (D)	P (W)	Conditional probabilities (%) P (DD)	P (WD)	P (WW)	P (DW)
1	100.0	0.0	–	–	–	–
2	96.8	3.2	96.8	3.2	0.0	100.0
3	96.8	3.2	96.7	3.3	0.0	100.0
4	100.0	0.0	100.0	0.0	0.0	100.0
5	100.0	0.0	100.0	0.0	0.0	100.0
6	100.0	0.0	100.0	0.0	0.0	100.0
7	100.0	0.0	100.0	0.0	0.0	100.0
8	100.0	0.0	100.0	0.0	0.0	100.0
9	100.0	0.0	100.0	0.0	0.0	100.0
10	96.8	3.2	96.8	3.2	0.0	100.0
11	100.0	0.0	100.0	0.0	0.0	100.0
12	100.0	0.0	100.0	0.0	0.0	100.0
13	96.8	3.2	96.8	3.2	0.0	100.0
14	90.3	9.7	90.0	10.0	0.0	100.0
15	93.5	6.5	96.4	3.6	33.3	66.7
16	96.8	3.2	96.6	3.4	0.0	100.0
17	90.3	9.7	90.0	10.0	0.0	100.0
18	93.5	6.5	92.9	7.1	0.0	100.0
19	83.9	16.1	82.8	17.2	0.0	100.0
20	93.5	6.5	96.2	3.8	20.0	80.0
21	77.4	22.6	75.9	24.1	0.0	100.0
22	67.7	32.3	70.8	29.2	42.9	57.1
23	58.1	41.9	57.1	42.9	40.0	60.0
24	87.1	12.9	94.4	5.6	23.1	76.9
25	93.5	6.5	92.6	7.4	0.0	100.0
26	93.5	6.5	93.1	6.9	0.0	100.0
27	93.5	6.5	93.1	6.9	0.0	100.0
28	80.6	19.4	79.3	20.7	0.0	100.0
29	77.4	22.6	84.0	16.0	50.0	50.0
30	71.0	29.0	75.0	25.0	42.9	57.1
31	87.1	12.9	86.4	13.6	11.1	88.9
32	74.2	25.8	74.1	25.9	25.0	75.0
33	90.3	9.7	91.3	8.7	12.5	87.5
34	83.9	16.1	82.1	17.9	0.0	100.0
35	77.4	22.6	73.1	26.9	0.0	100.0
36	80.6	19.4	91.7	8.3	57.1	42.9
37	71.0	29.0	68.0	32.0	16.7	83.3
38	64.5	35.5	72.7	27.3	55.6	44.4
39	51.6	48.4	65.0	35.0	72.7	27.3
40	54.8	45.2	50.0	50.0	40.0	60.0
41	64.5	35.5	70.6	29.4	42.9	57.1
42	77.4	22.6	85.0	15.0	36.4	63.6
43	77.4	22.6	75.0	25.0	14.3	85.7
44	71.0	29.0	70.8	29.2	28.6	71.4
45	90.3	9.7	90.9	9.1	11.1	88.9
46	90.3	9.7	92.9	7.1	33.3	66.7
47	96.8	3.2	100.0	0.0	33.3	66.7
48	100.0	0.0	100.0	0.0	0.0	100.0
49	93.5	6.5	93.5	6.5	0.0	100.0
50	93.5	6.5	93.1	6.9	0.0	100.0
51	100.0	0.0	100.0	0.0	0.0	100.0
52	96.8	3.2	96.8	3.2	0.0	100.0

Table 2. Consecutive dry and wet week probabilities of rainfall at Bellary.

SMW	Consecutive dry probabilities (%) 2D	3D	Consecutive wet probabilities (%) 2W	3W
1	96.8	93.5	0.0	0.0
2	93.5	93.5	0.0	0.0
3	96.8	96.8	0.0	0.0
4	100.0	100.0	0.0	0.0
5	100.0	100.0	0.0	0.0
6	100.0	100.0	0.0	0.0
7	100.0	100.0	0.0	0.0
8	100.0	96.8	0.0	0.0
9	96.8	96.8	0.0	0.0
10	96.8	96.8	0.0	0.0
11	100.0	96.8	0.0	0.0
12	96.8	87.1	0.0	0.0
13	87.1	84.0	0.0	0.0
14	87.1	84.1	3.2	0.0
15	90.3	81.3	0.0	0.0
16	87.1	80.9	0.0	0.0
17	83.9	69.4	0.0	0.0
18	77.4	74.4	0.0	0.0
19	80.6	61.2	3.2	0.0
20	71.0	50.3	0.0	0.0
21	54.8	31.3	9.7	3.9
22	38.7	36.6	12.9	3.0
23	54.8	50.8	9.7	0.0
24	80.6	75.1	0.0	0.0
25	87.1	81.1	0.0	0.0
26	87.1	69.1	0.0	0.0
27	74.2	62.3	0.0	0.0
28	67.7	50.8	9.7	4.1
29	58.1	50.1	9.7	1.1
30	61.3	45.4	3.2	0.8
31	64.5	58.9	3.2	0.4
32	67.7	55.6	3.2	0.0
33	74.2	54.2	0.0	0.0
34	61.3	56.2	0.0	0.0
35	71.0	48.3	12.9	2.2
36	54.8	39.9	3.2	1.8
37	51.6	33.5	16.1	11.7
38	41.9	21.0	25.8	10.3
39	25.8	18.2	19.4	8.3
40	38.7	32.9	19.4	7.0
41	54.8	41.1	12.9	1.8
42	58.1	41.1	3.2	0.9
43	54.8	49.9	6.5	0.7
44	64.5	59.9	3.2	1.1
45	83.9	83.9	3.2	1.1
46	90.3	90.3	3.2	0.0
47	96.8	90.5	0.0	0.0
48	93.5	87.1	0.0	0.0
49	87.1	87.1	0.0	0.0
50	93.5	90.5	0.0	0.0
51	96.8	–	0.0	–
52	–	–	–	–

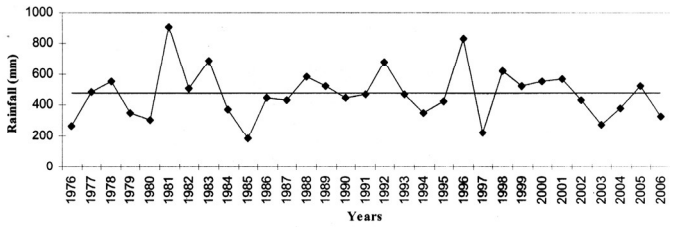

Figure 1. Annual rainfall pattern (1976—2006) at Bellary.

The dry and wet spell analyses were 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 (2). The different notations followed in this analysis are given below :

Initial Probability :

$$P_D = F_D / n \quad .....(1) \qquad P_w = F_W / n \quad .....(2)$$

Conditional Probabilities :

$$P_{DD} = F_{DD} / F_D \quad .....(3) \qquad P_{WW} = F_{WW} / F_W .....(4)$$

$$P_{WD} = 1 - P_{DD} \quad .....(5) \qquad P_{DW} = 1 - P_{WW} .....(6)$$

Consecutive dry and wet probabilities :

$$2D = P_{DW1} . P_{DDW2} .....(7) \quad 2W = P_{Ww1} . P_{WWw2} .....(8)$$

$$3D = P_{Dw1} . P_{DDw2} . P_{DDw3} .....(9)$$

$$3W = P_{Ww1} . P_{WWw2} . P_{WWw3} .....(10)$$

Where, P_D—Probability of the week being dry, P_W—Probability of the week being wet, F_D—Number of dry weeks, F_W—Number of wet weeks, n—Number of years of data, P_{DD}—Probability (conditional) of a dry week preceded by a dry week, P_{WW}—Probability (conditional) of a wet week preceded by a wet week, P_{WD}—Probability (conditional) of a wet week preceded by a dry week, P_{DW}—Probability (conditional) of a dry week preceded by a wet week, F_{DD}—Number of dry weeks preceded by another dry week, F_{WW}—Number of wet weeks preceded by another wet week, $2D$—Probability of 2 consecutive dry weeks starting with the week, $2W$—Probability of 2 consecutive wet weeks starting with the week, $3D$—Probability of 3 consecutive dry weeks starting with the week, $3W$—Probability of 3 consecutive wet

Table 3. Characterization of the rainy season at Bellary (1976—2006).

Particulars	Week No.	Date
Mean week of onset of rainy season	27	2—8 Jul
Earliest week of onset of rainy season	21	21—27 May
Delayed week of onset of rainy season	40	1—7 Oct
Mean week of withdrawal of rainy season	43	22—28 Oct
Earliest week of withdrawal of rainy season	37	10—16 Sep
Delayed week of withdrawal of rainy season	47	19—25 Nov
Mean length of rainy season	16 weeks (112 days)	
Duration of rainy season		
Highest	25 weeks (175 days)	
Lowest	4 weeks (28 days)	

Table 4. Probability (%) of onset and withdrawal of rainy season at Bellary. SMW–Standard meteorological week, P–Probability in percentage.

Probability (%) of Onset of Rainy Season											
SMW	21	22	23	24	25	26	27	28	29	30	31
P (%)	3.1	18.8	31.3	43.8	–	46.9	50.0	53.1	62.5	68.8	81.3
Probability (%) of Onset of Rainy Season											
SMW	32	33	34	35	36	37	38	39	40		
P (%)	–	84.4	90.6	–	–	93.8	–	–	96.9		
Probability (%) of Withdrawal of Rainy Season											
SMW	37	38	39	40	41	42	43	44	45	46	47
P (%)	3.1	–	6.3	15.6	18.8	28.1	43.8	71.9	84.4	93.8	96.9

weeks starting with the week, P_{Dw1}—Probability of the week being dry (first week), P_{DDw2}—Probability of the second week being dry, given the preceding week dry, P_{DDw3}—Probability of the third week being dry, given the preceding week dry, P_{Ww1}—Probability of the week being wet (first week), P_{WWw2}—Probability of the second week being wet, given the preceding week wet, and P_{WWw3}—Probability of the third week being wet, given the preceding week wet.

The onset and withdrawal of rainy season was computed from weekly rainfall data by forward and backward accumulation methods respectively. In this method weekly rainfall was summed by forward accumulation (20+21+.....+52 weeks) until a certain amount of rainfall was accumulated. Seventy five mm of rainfall accumulation was considered as the onset time for the growing season of dry seeded crops and land preparation (3, 4). The withdrawal of rainy season was determined by backward accumulation of rainfall (48+47+46+.....+30 weeks) data. Twenty mm of rainfall accumulation was chosen for the end of rainy season, which may be sufficient for ploughing of fields after harvesting of crops (3).

The percent probability (P) of each rank was calculated by the following Weibull's formula :

$$P = \frac{m}{N+1} \times 100 \qquad \ldots (11)$$

Where, m is the rank number and N is the number of years of data used.

The weekly rainfall analysis was carried out to find out mean, maximum, minimum, standard deviation, coefficient of variation and percentage of rainfall contribution on weekly basis.

Results and Discussion

The initial and conditional probabilities of occurrence of dry and wet weeks are presented in Table 1. The results revealed that the occurrence of dry week was high throughout all standard meteorological weeks and ranged more than 70% during all weeks except smw (Standard Meteorological Week) 22—23 and smw 38—41. On contrary, the probability of occurrence of wet week was low (less than 30%) during all standard meteorological weeks except smw 22—23 and 38—41. The probability of occurrence of dry week is always contrary to the wet week both making up to 100%. The probability of occurrence of dry week preceded by another dry week and that of dry week preceded by another wet week varied from 50 to 100% and from 27.3 to 100% respectively during all standard meteorological weeks. The probability of occurrence of wet week preceded by another wet week was found to be 0% during smw 1—14, 16—19, 21, 25—28, 34—35 and 48—52. However in the remaining weeks it was less than 50% except during smw 29, 36 and 38—39. Throughout the year, the probability of occurrence of wet week preceded by dry week ranged from 0 to 50%.

The analysis of consecutive dry and wet spells revealed that the probability of occurrence of two consecutive dry weeks was more than 75% during smw 1—19, 24—26 and after smw 44 (Table 2). Simi-

Table 5. Weekly rainfall attributes at Bellary (1976—2006).

SMW	Mean	Max	Min	SD	CV	Percent of ARF
1	0.39	6.90	0.00	1.32	338.81	0.08
2	2.71	57.70	0.00	10.56	390.23	0.57
3	1.42	26.70	0.00	5.35	376.64	0.30
4	0.00	0.00	0.00	–	–	0.00
5	0.17	4.30	0.00	0.78	467.23	0.04
6	0.78	9.40	0.00	2.10	269.24	0.16
7	0.03	0.80	0.00	0.14	556.78	0.01
8	0.91	17.20	0.00	3.43	376.80	0.19
9	0.43	5.50	0.00	1.33	312.97	0.09
10	1.62	39.20	0.00	7.07	436.49	0.34
11	0.35	10.00	0.00	1.79	514.90	0.07
12	0.45	6.10	0.00	1.42	313.40	0.10
13	1.12	24.50	0.00	4.47	400.56	0.23
14	3.22	26.60	0.00	7.81	242.49	0.68
15	4.66	38.10	0.00	9.71	208.49	0.98
16	4.31	38.00	0.00	8.10	188.15	0.91
17	7.57	65.10	0.00	14.79	195.30	1.59
18	5.05	43.20	0.00	9.90	196.17	1.06
19	13.76	85.80	0.00	23.57	171.26	2.90
20	6.48	31.30	0.00	8.34	128.68	1.37
21	13.64	103.40	0.00	23.29	170.77	2.87
22	20.79	111.20	0.00	28.83	138.68	4.38
23	21.32	143.80	0.00	27.13	127.25	4.49
24	13.19	96.40	0.00	22.13	167.83	2.78
25	5.23	24.60	0.00	6.85	130.93	1.10
26	6.87	81.80	0.00	15.20	221.05	1.45
27	7.27	67.00	0.00	16.12	221.61	1.53
28	11.81	74.70	0.00	17.50	148.22	2.49
29	11.99	89.70	0.00	20.81	173.54	2.52
30	14.34	75.80	0.00	20.92	145.92	3.02
31	8.72	60.40	0.00	13.07	149.86	1.84
32	13.93	85.60	0.00	21.75	156.11	2.93
33	8.03	70.00	0.00	13.77	171.44	1.69
34	9.71	57.10	0.00	14.25	146.70	2.04
35	20.82	153.70	0.00	37.72	181.18	4.38
36	11.14	70.10	0.00	17.10	153.57	2.34
37	20.05	106.10	0.00	30.30	151.15	4.22
38	33.92	188.10	0.00	50.15	147.84	7.14
39	33.03	191.10	0.00	42.05	127.31	6.95
40	31.18	115.80	0.00	34.88	111.88	6.56
41	30.11	142.70	0.00	41.39	137.48	6.34
42	15.73	117.60	0.00	25.31	160.96	3.31
43	14.63	97.20	0.00	21.38	146.11	3.08
44	12.26	91.60	0.00	20.23	165.04	2.58
45	8.28	55.90	0.00	14.41	173.99	1.74
46	10.17	130.80	0.00	26.26	258.13	2.14
47	2.12	45.50	0.00	8.27	390.83	0.45
48	0.89	16.80	0.00	3.11	349.59	0.19
49	3.63	78.50	0.00	14.55	401.32	0.76
50	2.60	41.90	0.00	8.89	341.79	0.55
51	0.12	3.80	0.00	0.68	556.78	0.03
52	2.07	38.20	0.00	7.39	356.39	0.44

larly, the probability of occurrence of three consecutive dry weeks was also more than 75% during smw 1—16, 24—25 and after smw 44. The probability of 2 and 3 consecutive dry weeks during rainy season (smw 20—48) ranged from 25.8 to 96.8% and 18.2 to 90.5% respectively. The probabilities of two and three consecutive wet weeks during rainy season were low and ranged from 0 to 25.8 and 0 to 11.7% respectively.

The data on onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability at Bellary region are presented in Table 3. Weekly rainfall data of 31 years(1976—2006) indicated that the monsoon starts effectively from smw 27 (2—8 July) and remains active up to smw 43 (22—28 October).Therefore, mean length of rainy season was found to be 16 weeks (112 days). The earliest and delayed week of onset of rainy season was smw 21 (21—27 May) and smw 40 (1—7 October) respectively. Similarly the earliest and delayed week of cessation of rainy season was smw 37 (10—16 September) and smw 47 (19—25 November) respectively. The highest and lowest length of rainy season was 25 and 4 weeks respectively. The probabilities of onset and withdrawal of rainy season was calculated by using Weibull's formula and results are presented in Table 4. The results revealed that there is more than 80% chance that the onset of rainy season and cessation of rainy season will occur during smw 31 and 45, respectively.

The weekly rainfall and annual rainfall analyses over Bellary are presented in Table 5 and Fig. 1 respectively. The total annual rainfall ranged between 188.2 mm (1985) to 914.1 mm (1981) with the average annual rainfall of 475.0 mm and coefficient of variation (CV) of 34.47% (Fig. 1). The weekly mean rainfall (Table 5) during the last 31 years ranged between 0.00 mm (smw 4) to 33.92 mm (smw 38). Considering weekly mean rainfall, there found only a total of 8 weeks (smw 22—23, 35 and 37—41) when rainfall exceeded more than 20 mm in a week. The average maximum weekly rainfall ranged from 0.0 mm (smw 4) to 191.1 mm (smw 39) and analysis of weekly minimum rainfall revealed that the minimum rainfall of 0.00 mm has occurred during all the standard meteorolo-

gical weeks in a year in one or the other time. The weekly contribution of rainfall when compared to average annual rainfall was found to be highest during smw 38 (7.14%) and lowest in smw 4 (0.00%). The standard deviation ranged from 0.14 (smw 7) to 50.15 (smw 38). With the present analysis, the results are much usefull in planning agricultural operations, selection of short duration crops which suits for delayed sowing and selection of suitable water harvesting and soil and water conservation measures by the agronomists and agricultural engineers for the Bellary region.

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