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Statistical Analysis of Weekly Rainfall of 25 years (1986-2010) using Markov Chain Probability Model for Agricultural Planning in Southern Telangana Zone of Andhra Pradesh

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ABSTRACT

For successful agricultural crop management and planning of soil and water conservation measures it is necessary to know the sequence of dry and wet periods along with onset and withdrawal of rainy season. In this study, markov chain model has been used to study wet and dry spell distribution in monsoon period, onset and withdrawal of monsoon and weekly analysis of rainfall for Ranga Reddy district of South Telangana zone. The average rainfall of this region is 835.5 mm. Coefficient of Variation (CV) of weekly rainfall of Rajendranagar was 23.52% showing slightly erratic distribution of rainfall. The data on onset and withdrawal of monsoon indicated that the monsoon starts effectively from 24th Standard Meteorological Week (SMW) (11-17th June) and remains active up to 43rd SMW (22nd -28th October). The probability of occurrence of dry week is maximum in 44th SMW (88%) followed by 22nd SMW (92%). The probability of occurrence of dry week ranged from 36-72% from 23rd – 39th SMW. The probability of occurrence of dry week after dry week is 100% in 23rd SMW followed by 77 percent in 30th SMW and 66 percent in 23 SMW. The probability of occurrence of wet week is more than 40% throughout crop growth period (22-44 SMW) except during 22nd SMW and 40th, 42nd & 44th SMW. The probability of occurrence of wet weeks is maximum in 30th, 32nd and 33rd (64%) SMW followed by 31st SMW (60%). The probability of wet week after wet week is highest in 30th (68%) followed by 34th (64%) SMW. The results through analysis have been used for agricultural planning at Rangareddy region.

Key words : Conditional probability, Length of crop growing season, Markov chain model, Wet and dry spell, Onset and Withdrawal of rainy season.

Rangareddy district (17^0 12’ 00" N and 78^0 16’ 48" E) is situated in southern Telangana zone of Andhra Pradesh with a geographical area of 7.5 lakh ha and has a semiarid climate. Nearly 1.497 lakh ha of the cultivated area is rainfed and crop yields are thus dependent on rainfall characteristics (http://www.agricoop.nic.in). The quantity of rainfall received and the sequential phenomenon of dry and wet spells over a period of time at any location provides a general picture on its sufficiency to meet crop needs. The concept of estimating probabilities with respect to a given amount of rainfall is extremely useful for agricultural operational planning.

Markov analysis looks at a sequence of events and analyses the tendency of one event to be followed by another. Using this analysis, we can generate a new sequence of random but related events, which will look similar to the original. Pandarinath (1991) used the Markov Chain Model to study the probability of dry and wet spells in Andhra Pradesh. Another aspect useful for crop planning is forward and backward accumulation of rainfall to determine the onset and withdrawal of rainy season.

The present study has been carried out to find the probabilities of occurrence of one and two consecutive dry and wet weeks, onset and withdrawal of rainy season for Rajendranagar, Rangareddy region using Markov Chain Model.

MATERIAL AND METHODS

Weekly rainfall data of 25 years (1986-2010) was taken from Meteorological Observatory located at Agricultural Research Institute, Acharya N. G. Ranga Agricultural University, Hyderabad.

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 20mm or more as a wet week (Pandarinath, 1991). For this purpose a Standard meteorological Week (SMW) period was considered as the optimum length of time.

The different notations followed in this analysis are given below:

Initial probability:

$$P_D = F_D / N$$
$$P_W = F_W / N$$

Conditional Probability:

$$P_{DD} = F_{DD} / F_D$$
$$P_{WW} = F_{WW} / F_W$$

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

P_{DD} – Probability of a dry week being followed by dry week

P_{WW} – Probability of a wet week being followed by wet week

F_{DD} – Number of dry weeks followed by a dry week

F_{WW} – Number of wet weeks followed by a wet week.

Onset and withdrawal of rainy season was computed from weekly rainfall data by forward and backward accumulation methods. 75 mm of forward accumulation of rainfall (20+21+….+52) has been considered as the onset of growing season of dry seeded crops and land preparation (Panigrahi and Panda, 2002). 20 mm of backward accumulation of rainfall (48+47+…+30) has been considered as end of rainy season, which is sufficient for ploughing of fields after harvesting the crops (Babu and Lakshminarayana, 1997)

Estimation of normal, wet and dry years is done based on Mean Deviation method and also according to IMD.

Based on Mean Deviation Method:

Normal Rainfall = Average Rainfall ± 2×Mean Deviation

Wet year: If the actual rainfall > Average Rainfall + 2×Mean Deviation

Dry year: If the actual rainfall < Average Rainfall - 2×Mean Deviation

According to IMD:

Normal year = Average Rainfall ± 25% Deficit or 25% excess

Moderate Drought year: 25% - 50% deficit in average rainfall

Severe Drought year: > 50% deficit in average Rainfall.

RESULTS AND DISCUSSION

Analysis of rainfall data of 25 Years (1986-2010) revealed that the annual rainfall ranged between 634.9 mm (1986) to 1420.5 mm (1995) with an average rainfall of 835.5 mm. Coefficient of Variation (CV) of weekly rainfall of Rajendranagar was 23.52% showing slightly erratic distribution. The rainfall data of 25 years (standard week wise) from 1986-2010 were presented in Table 1.

The data on onset, withdrawal of monsoon and duration of the crop growing season (difference between onset and withdrawal time) and its variability was represented in Table 2. Weekly rainfall data of 25 years (1986-2010) indicated that the monsoon starts effectively from 24th SMW (11-17th June) and remains active up to 43rd SMW (22nd -28th October). Therefore, mean length of rainy season was found to be 19 weeks (133 days). The earliest and delayed onset of rainy season was 23rd SMW (4-10th June) and 29th SMW (16-22th July) respectively. Similarly the earliest and delayed week of cessation of rainy season was 39th SMW (24-30th Sep) and 47th SMW (19-25th Nov) respectively. The longest and shortest length of rainy season was 24 and 10 weeks respectively.

The number of normal, wet and dry years in this region from 1986-2010 were calculated using IMD method and also based on Mean deviation method. Out of 25 years, the analysis showed that twenty three are normal years, two are wet years (1995& 2008) and no dry year was experienced in this region (Mean Deviation Method). According to IMD method, 21 years received normal rainfall while 4 wet years (1995, 1998, 2008 and 2010) were observed with annual rainfall more than normal rainfall. Over the 25 years, no drought year was experienced.

The results pertaining to initial and conditional probabilities of dry and wet weeks of rainy season (22nd SMW – 44th SMW) are presented in Table 3. The probability of occurrence of wet weeks is maximum in 30th, 32nd and 33rd (64%) SMW followed by 31st SMW (60%). The probability of wet week after wet week is highest

Table 1. Rainfall data of Rangareddy district (mm) (Standard week wise) from 1986-2010.

WEEK	1	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NO.	PERIOD																
22	28-03	8.2	7.1	0.0	2.0	1.4	0.0	32.7	18.2	0.0	0.0	1.6	0.0	0.0	0.0	25.0	9.0
	JUN																
23	04-10	1.4	3.4	9.6	24.1	30.7	63.4	44.0	0.0	8.4	0.0	42.0	12.4	0.0	9.8	52.1	61.0
24	11-17	88.1	43.6	3.8	15.4	61.6	85.6	0.0	0.0	19.2	34.0	67.2	52.6	10.4	22.4	113.9	96.4
25	18-24	32.2	0.0	48.4	40.8	48.4	8.5	35.9	2.8	3.4	61.8	0.0	6.0	35.8	21.4	37.4	8.2
26	25-01	10.0	54.2	0.0	38.0	6.0	3.2	43.8	38.8	16.7	40.0	20.0	0.0	4.9	15.8	66.9	0.8
27	02-08	0.0	75.2	16.9	53.8	7.2	16.6	106.8	4.2	44.4	114.2	20.5	72.8	0.8	71.9	25.2	3.7
	JUL																
28	09-15	2.8	75.1	82.2	23.0	43.8	129.8	102.2	13.8	15.8	4.4	15.2	13.2	9.2	34.2	29.1	6.2
29	16-22	52.4	0.0	81.3	137.0	38.1	5.4	3.4	8.4	27.0	61.2	72.4	8.4	62.6	60.8	1.9	11.2
30	23-29	0.0	0.6	37.3	160.7	27.2	1.8	17.8	55.5	30.0	106.4	29.2	36.6	118.8	16.6	0.6	10.9
31	30-05	60.2	22.8	47.2	0.0	1.8	30.6	32.9	53.3	1.0	19.1	7.6	0.4	66.1	67.7	2.7	72.2
	AUG																
32	06-12	105.0	50.9	31.9	36.4	50.8	69.4	94.6	9.6	33.2	1.8	34.2	18.7	71.7	8.8	95.0	93.2
33	13-19	54.0	59.3	81.9	41.2	128.2	7.3	21.6	14.2	50.6	10.6	37.6	15.3	12.2	40.6	49.7	1.4
34	20-26	13.2	11.9	11.8	11.5	18.4	16.2	0.0	14.8	35.0	71.0	79.2	2.2	116.3	15.3	164.9	1.4
35	27-02	1.2	6.6	72.8	6.4	18.3	0.0	32.8	64.5	34.4	89.2	67.7	80.0	23.2	24.6	19.9	0.0
	SEP																
36	03-09	22.8	21.6	59.0	20.7	15.2	1.8	0.0	33.2	1.7	0.0	54.2	76.0	25.5	28.4	1.2	17.4
37	10-16	8.6	18.4	11.0	84.0	12.4	155.4	42.2	0.0	14.4	139.8	151.8	1.6	11.0	1.9	3.0	10.5
38	17-23	9.0	2.2	32.8	76.2	9.0	0.0	0.0	101.4	31.6	19.8	2.0	47.5	122.2	1.8	35.6	23.4
39	24-30	14.8	2.5	33.6	28.0	29.9	2.8	3.6	0.0	0.0	20.0	2.8	0.0	38.6	23.4	10.0	96.4
40	01-07	0.2	19.3	0.0	13.8	62.6	46.4	9.8	15.8	210.0	0.0	78.2	6.2	63.0	14.6	0.0	139.6
	OCT																
41	08-14	0.0	3.4	0.0	0.0	58.4	0.0	32.8	33.7	2.8	114.8	0.0	0.0	50.3	8.4	8.4	27.4
42	15-21	0.0	21.2	0.0	0.0	0.0	2.2	0.0	21.4	2.6	157.0	20.6	0.0	122.1	3.2	12.8	31.1
43	22-28	0.0	0.0	0.0	0.0	23.6	6.0	2.6	5.0	16.2	11.2	10.2	12.4	1.4	42.4	0.0	0.0
44	29-04	11.4	147.8	0.0	0.0	0.0	0.0	0.0	0.7	27.4	0.0	0.0	54.5	10.5	0.0	0.8	0.0
	NOV																

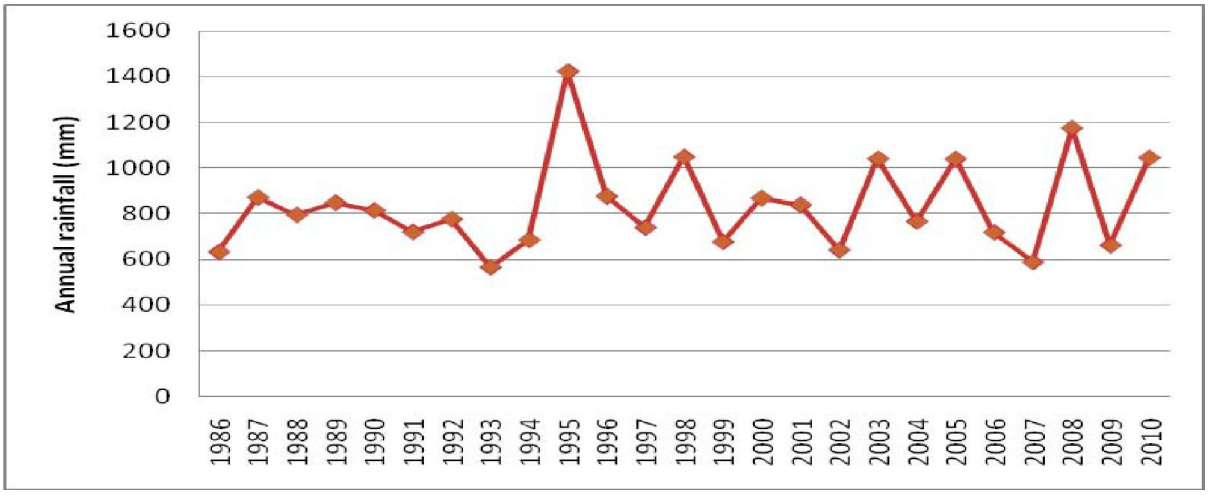

Fig 1: Annual rainfall pattern (1986-2010) at ANGRAU, Rajendranagar.

The rainfall for 25 years (1986-2010) is as follows : 634.9, 872.3, 796.7,849.4, 816.3, 722.6, 777.9, 568.1, 686.5, 1420.5, 877.6, 741.1, 1050.1, 678.4, 869.4, 840.0, 643.0, 1041.6, 768.0, 1040.6, 720.3, 590.9, 1174.3, 663.2 and 1045.7 mm.

Table 1 cont....

WEEK		2002	2003	2004	2005	2006	2007	2008	2009	2010
NO.	PERIOD									
22	28 May-03 Jun	18.4	0.0	0.0	3.2	5.6	0.6	0.7	0.0	16.6
23	04-10 June	49.4	12.0	23.2	0.0	3.4	14.2	5.7	36.4	0.0
24	11-17	0.0	54.6	26.4	10.2	13.8	6.8	20.5	13	2.4
25	18-24	33.8	9.8	3.8	0.0	17.9	55.6	0.2	32.6	28.1
26	25 -01 JUL	11.3	3.3	2.8	26.2	3.8	57.1	39.6	0.0	83.2
27	02-08	9.3	50.8	33.6	35.2	5.9	0.0	0.0	27.2	1.0
28	09-15	16.2	130.4	85.2	134.6	0.0	39.0	4.1	6.4	96.8
29	16-22	41.6	70.2	31.0	35.4	0.0	6.4	12.8	17.8	59.4
30	23-29	48.2	50.2	122.0	83.1	80.5	0.0	65.2	2	82.1
31	30 July-05 Aug	10.8	70.0	34.0	11.8	116.5	54.0	120.2	0.6	30.6
32	06-12	95.4	91.6	0.0	10.4	3.6	20.7	188.8	2.5	13.8
33	13-19	8.6	1.2	34.0	54.1	16.2	5.0	23.2	41.6	25.2
34	20-26	35.2	118.2	0.0	2.4	44.2	48.0	157.3	103.4	64.5
35	27 Aug-02 Sep	7.6	1.0	1.6	65.4	32.1	56	18.4	87.6	73.6
36	03-09	17.4	6.2	26.8	110.2	18.6	24.4	98.2	10	35.0
37	10-16	0.0	0.6	60.4	5.6	53.4	39.2	104.6	8.2	42.4
38	17-23	1.4	4.8	38.2	71.4	49.0	53.6	1.8	3.6	26.4
39	24-30 Sep	0.0	32.4	0.6	30.0	43.50	23.3	0.0	112.3	85.4
40	01-07 OCT	0.2	13.4	4.8	0.0	4.5	6	49.4	45	75.8
41	08-14	84.0	13.1	32.4	30.6	0.0	0.0	3	51	27.8
42	15-21	74.8	40.6	13.4	76.9	0.0	2.8	1.2	0.0	0.0
43	22-28	0.0	49.2	13.1	30.6	0.8	0.0	0.0	0.0	47.2
44	29 Oct-04 Nov	0.0	8.6	40.6	11.7	39.1	21.8	0.0	0.0	32.2

Table 2. Characterization of Rainy season at ANGRAU, Rajendranagar.

Particulars	SMW no.	Date
Mean week of onset of rainy season	24	June 11-17
Earliest week of onset of rainy season	23	June 4-10
Delayed week of onset of rainy season	29	July 16-22
Mean week of withdrawal of rainy season	43	Oct 22-28
Earliest week of withdrawal of rainy season	39	Sep 24-30
Delayed week of withdrawal of rainy season	47	Nov – 19-25

SMW- Standard Meteorological Week

Table 3. Initial and conditional probabilities of rainfall calculated at ARI, Rajendranagar for 25 years.

SMW	PERIOD	Probability of dry spells (%)				Probability of wet spells (%)			
		F_D	$P_{(D)}$	F_{DD}	$P_{(DD)}$	$F_{(w)}$	$P_{(W)}$	$F_{(WW)}$	$P_{(WW)}$
22	28-03 JUN	23	92	-	-	2	8	0	-
23	04-10	15	60	15	0	10	40	2	20
24	11-17	12	48	8	66	13	52	6	46
25	18-24	12	48	4	33	13	52	5	38
26	25-01 JUL	14	50	7	50	13	44	6	54
27	02-08	12	48	8	66	13	52	6	46
28	09-15	12	48	7	58	13	52	7	53
29	16-22	11	44	6	54	14	56	8	57
30	23-29	9	36	7	77	16	64	11	68
31	30-05 AUG	10	40	2	20	15	60	8	53
32	06-12	9	36	4	44	16	64	10	62
33	13-19	9	36	4	44	16	64	10	62
34	20-26	13	52	3	23	12	48	6	50
35	27-02 SEP	11	44	7	63	14	56	8	57
36	03-09	11	44	6	54	14	56	9	64
37	10-16	15	60	7	46	10	40	6	60
38	17-23	12	48	7	58	13	52	5	38
39	24-30	12	48	7	58	13	52	8	61
40	01-07 OCT	16	64	8	50	9	36	5	55
41	08-14	14	56	10	71	11	44	5	45
42	15-21	16	64	11	68	9	36	6	66
43	22-28	20	80	14	70	5	20	2	40
44	29-04 NOV	18	72	14	77	7	28	1	14

P_D – Probability of the week being dry, P_W – Probability of the week being wet, P_{DD} – Probability of a dry week being followed by dry week, P_{WW} – Probability of a wet week being followed by wet week.

in 30th (68%) followed by 34th (64%) SMW. The probability of occurrence of wet week is more than 40% throughout crop growth period (22-44 SMW) except during 22th SMW and 40th, 42nd & 44th SMW. The probability of sequence of wet weeks can indicate the adequacy of water and gives an idea of optimum water availability for rainwater harvesting and to take up suitable measures to control soil erosion.

The probability of occurrence of dry week is maximum in 44th SMW (88%) followed by 22nd SMW (92%). The probability of occurrence of dry week ranged from 36-72% from 23rd – 39th SMW. The probability of occurrence of dry week after dry week is 100% in 23rd SMW followed by 77 percent in 30th SMW and 66 percent in 23 SMW which may affect initial plant growth due to early season dry spell. In such a case, pot watering to seedlings and mulching to reduce evaporation losses can be recommended to improve germination and establishment of crops. Mulching and other moisture conservation practices will help in reducing soil

evaporation and conserve moisture in top layers of the soil (Reddy *et al.,* 2008). The probability of occurrence of dry week after dry week is more than between 41st – 44th SMW. Hence there is a chance of terminal drought in long duration crops. The probability of sequence of dry weeks indicates the need to practice supplementary irrigation and moisture conservation practices to avoid the risk of crop failure. Foliar application of 2% urea or 1% potassium nitrate can be done in crops like cotton and red gram and nipping of auxillary buds can be recommended in castor.

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