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RAINFALL CHARACTERISTICS ANALYSIS OF KUTCH (GUJARAT) REGION OF INDIA

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ABSTRACT

The rainfall characteristics analysis of Kutch district (Gujarat), India based on the rainfall data of 12 stations for the period 1901 to 1989 revealed that the rainfall has decreasing trend from SW region to NE region. Probability of weekly rainfall distribution worked out by ranking order method revealed that interior part of the district is more prone to drought conditions as compared to coastal plains. Most of the stations had recorded highest observed rainfall values nearer to the estimated rainfall of 100 years return period except at Bhuj, Anjar and Rahapur.

INTRODUCTION

Kutch is one of the low crop productivity districts of the Gujarat state where more than 85 per cent of the net sown area is under rainfed agriculture. The district lies between 22°45′ and 24°15′ N latitude and 68°15′ and 71°10′ E longitude with an area of 45,652 sq. km. The district has a long coastal belt and also border with Pakistan. It has live stock population of about 1.71 millions and human population of 10,50,161 (Census of India 1981).

The annual rainfall across the district varies from 338.4 mm to 451.9 mm about 90 per cent of which is received in Kharif season i.e. June to September. Both, the quantum of rainfall across the district and the pattern of distribution within the season are highly variable. Hence it becomes essential to have a better understanding of the rainfall variability as well as the probable periods of assured rainfall for appropriate crop production strategies in the region.

MATERIAL AND METHODS

Daily rainfall data for 12 raingauge stations in the Kutch district supplied by India Meteorological Department for the period 1901-1989 have been analysed for variation in annual and monthly rainfall. The Fig. 1 depicts the location of these stations in the district along with annual distribution and coefficient of variation of rainfall.

The data have also been utilised to compute the assured weekly rainfall distribution at different probability levels (onset and end of the moist period and dry and

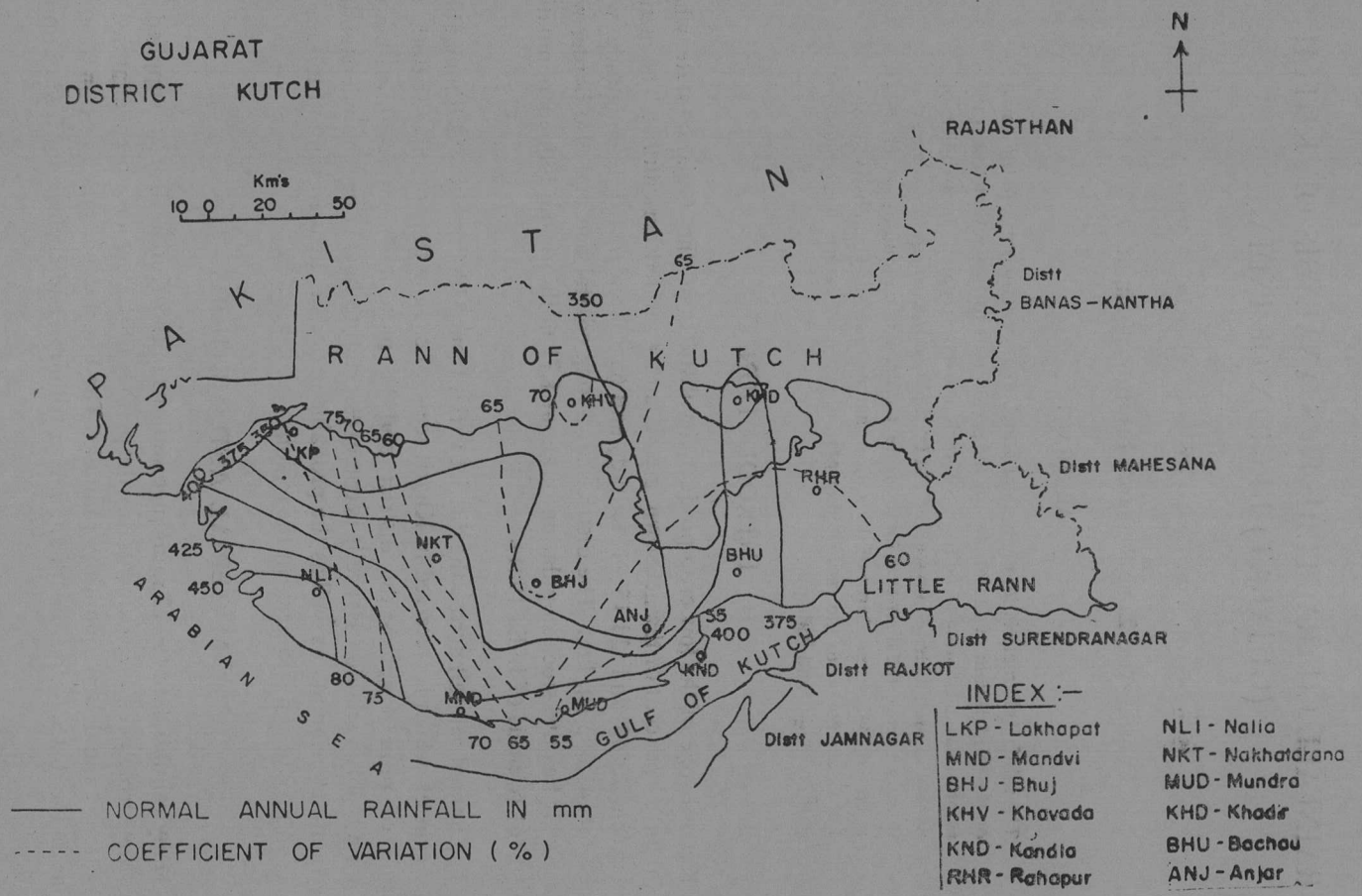

Fig. 1 Mean annual rainfall and its coefficients of variation over kutch region.

wet spells) with respect to two stations, namely, Bhuj representing interior part and Kandla representing coastal and south eastern part of the district.

RESULTS AND DISCUSSION

The study has been reported in four parts viz. annual and monthly rainfall, weekly rainfall, wet and dry spells and the one day heavy falls.

(i) Annual and monthly rainfall

The annual and monthly rainfall for six representative stations out of 12 stations in the district are presented in Table 1. Annual rainfall (Fig. 1) in the district has in

Table 1. Normal monthly and annual rainfall in Kutch district

Months/ Station	Anjar			Bhuj			Rahapur		
	Mean (mm)	CV (%)	RD	Mean (mm)	CV (%)	RD	Mean (mm)	CV (%)	RD
Jan.	1.5	382.2	0.1	2.2	205.6	0.3	0.6	372.0	0.1
Feb.	2.0	334.7	0.2	3.7	298.7	0.3	1.5	308.6	0.2
March	1.3	527.6	0.1	2.5	342.0	0.2	1.0	504.0	0.1
April	0.6	390.7	0.1	0.8	320.7	0.1	0.6	743.9	0.1
May	3.6	497.7	0.2	5.2	504.5	0.2	4.3	312.3	0.3
June	41.8	158.6	1.9	29.4	134.7	1.5	41.4	171.7	1.8
July	152.0	90.0	6.4	145.1	97.6	5.6	140.1	87.9	5.7
Aug.	86.8	124.0	4.3	96.3	111.3	4.1	101.7	111.6	4.7
Sept.	42.8	143.4	2.4	43.5	134.9	2.1	56.5	160.9	2.4
Oct.	8.8	290.3	0.5	9.4	297.5	0.4	11.7	321.1	0.5
Nov.	3.9	364.9	0.2	4.8	377.2	0.3	4.0	423.8	0.2
Dec.	1.0	366.1	0.1	0.8	432.8	0.1	1.2	454.2	0.1
Annual	343.5	56.1	16.5	342.4	65.6	15.2	365.5	61.1	16.2

Months/ Station	Lakhapat			Nalia			Kandla		
	Mean (mm)	CV (%)	RD	Mean (mm)	CV (%)	RD	Mean (mm)	CV (%)	RD
Jan.	0.0	0.0	0.0	0.4	313.7	0.1	1.6	270.3	0.2
Feb.	0.0	0.0	0.0	0.8	494.4	0.0	1.9	288.7	0.2
March	0.0	0.0	0.0	2.1	529.2	0.0	2.6	444.4	0.2
April	0.0	0.0	0.0	0.1	529.2	0.0	0.1	547.7	0.0
May	0.4	538.5	0.0	0.1	529.2	0.0	0.4	321.3	0.1
June	34.1	132.8	1.5	40.2	171.2	1.8	57.9	107.9	2.6
July	120.1	125.1	4.6	202.5	115.9	5.0	160.6	79.6	7.4
Aug.	113.6	172.2	3.3	122.8	146.6	4.2	119.6	100.3	5.5
Sept.	61.5	179.5	2.4	71.8	189.4	2.0	53.7	118.8	3.0
Oct.	2.2	376.5	0.1	2.5	419.0	3.2	13.9	280.7	0.6
Nov.	5.1	339.1	0.2	7.2	283.7	0.3	11.8	317.0	0.5
Dec.	1.3	398.0	0.1	1.5	362.8	0.1	5.5	522.5	0.1
Annual	338.4	78.8	12.0	451.9	80.7	13.7	433.2	52.4	20.4

CV = Coefficient of variation RD = Rainy days

general decreasing trend from SW to NE direction and the annual rainfall varies from 338.4 mm at Lakhapat to 451. 9 mm at Nalia. The contribution of south west monsoon (June-September) is about 90 per cent to annual rainfall of the region. July is the rainiest month of the year at all the stations except at Lakhapat (August). On an average there are 15.4 rainy days (i.e. days with rainfall of 2.5 mm or more) in an year in the district. The number of rainy days varies from 11.7 at Khavhda the interior plain to 20.4 days at Kandla in coastal areas. The coefficient of variation of annual rainfall at Nalia is 80.7% where as at Bhuj it is (65.6%). It further decreases towards the eastern coastal region and is lowest (52.4%) at Kandla (Fig.1).

To know rainfall amount at different probabilities over Bhuj, Rahapur and Mundra the ranking order method was followed and values plotted on log pearson type III distribution (Fig. 2). The study revealed that probability of getting 300 mm annual rainfall at Mundra (coastal station) is about 67 % while at Bhuj (interior part) it is about 50 %. Hence pearlmillet crop, which generally requires about 300 mm of rainfall, can be grown successfully in two years out of three years in Mundra region and at every alternate year in Bhuj region of the district provided temporal distribution of rainfall is also normal over the region.

(ii) Weekly rainfall distribution

Weekly rainfall totals for the standard meteorological weeks No. 22 to 44 (June to October) for all 12 stations and for all the period under study revealed that the highest mean weekly rainfall was recorded generally either in first fortnight of July

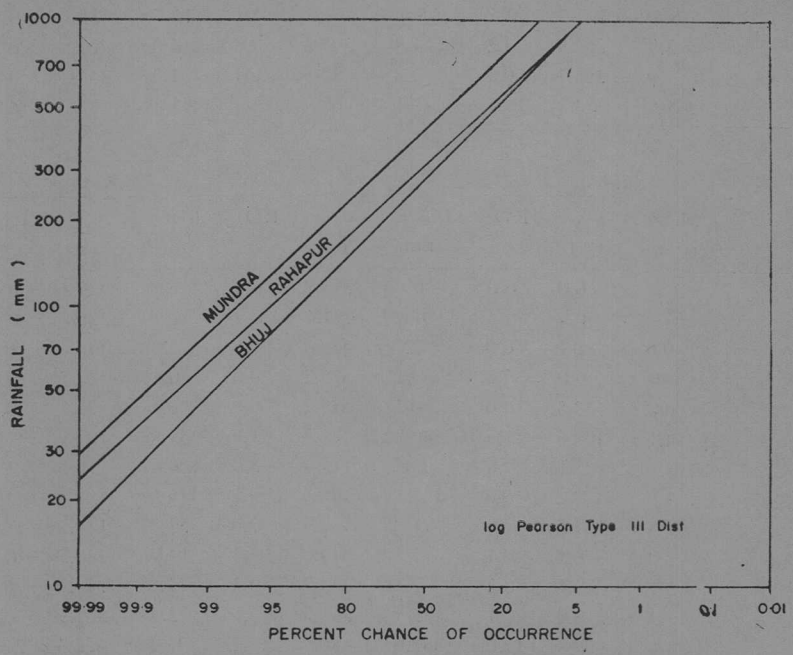

Fig. 2. Probability of occurrence of annual rainfall at three representative stations of kutch district.

or in the first fortnight of August thereby indicating late occurrence of active monsoon conditions. A secondary maxima of weekly rainfall is also observed in respect of some stations, associated with the withdrawal of monsoon.

Amount of assured rainfall at different probability levels was also worked out by ranking order method for Bhuj and kandla station (Table 2). The data revealed that Bhuj region dose not have much assured rainfall even at 33.3% probability level, thereby indicating higher risk in crop production in this region. However the amount of assured rainfall at 33.3% probability is significantly high in Kandla region which can promote successful kharif crop production. Thus it could be concluded that interior part of the district is more prone to drought conditions as compared to coastal plains.

Table 2. Weekly rainfall (mm) at different probability levels during monsoon period at Bhuj and Kandla locations.

Week No.	Mean		Probability Level							
			25%		33.3%		50%		66.6%	
	Bhuj	Kandla	Bhuj	Kandla	Bhuj	Kandla	Bhuj	Kandla	Bhuj	Kandla
22	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	2.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	7.4	6.0	0.0	2.2	0.0	1.3	0.0	0.0	0.0	0.0
25	6.9	23.0	2.8	30.6	0.0	14.8	0.0	0.3	0.0	0.0
26	16.0	33.0	9.5	49.2	7.1	36.2	0.0	11.0	0.0	0.3
27	33.2	39.0	30.9	94.4	20.8	29.0	5.2	6.8	0.6	2.2
28	39.9	34.0	38.3	72.0	22.4	27.1	7.0	16.0	0.4	6.8
29	25.9	37.0	22.6	79.7	13.2	34.0	3.1	12.5	0.6	3.2
30	29.2	43.0	39.1	59.2	23.9	49.5	6.0	11.0	0.6	2.0
31	29.4	30.0	39.4	38.8	14.7	11.6	2.8	6.1	0.3	2.4
32	22.6	25.0	17.8	37.6	9.1	16.3	1.5	7.2	0.3	3.6
33	24.5	28.0	35.3	33.2	15.4	25.1	1.3	9.6	0.0	2.2
34	13.5	9.0	17.8	11.4	5.6	3.2	0.4	1.2	0.0	0.0
35	19.5	30.0	17.0	36.0	5.5	28.2	0.7	1.6	0.0	0.6
36	19.1	25.0	14.2	54.1	2.0	31.6	0.0	3.2	0.0	0.4
37	5.8	16 0	2.3	9.8	0.3	1.8	0.0	0.0	0.0	0.0
38	3.0	28.0	0.3	3.0	1.0	1.0	0.0	0.0	0.0	0.0
39	3.6	3.0	0.9	1.0	0.0	0.5	0.0	0.0	0.0	0.0

(iii) Wet and dry spells

Occurrence of dry and wet spells were studied for better crop management in Kandla region based on the Markov chain model as described by Robertson (1976) and the results are presented in Table 3. In this model a dry week (spell) is defined as that week which received less than 10 mm, otherwise considered as wet week. This analysis revealed that the occurrence of wet week increases sharply in Kandla areas from 25th to 37th standard weeks with highest probability (64.5%)

Table 3. Conditional probability (%) of wet week followed by dry and wet weeks at Kandla

Week No.	Initial probabilities of wet weeks (in %)	Conditional probability							
		W/1D	W/2D	W/3D	W/4D	W/1W	W/2W	W/3W	W/4W
22	0.0	0	0	0	0	0	0	0	0
23	6.5	100	100	50	50	0	0	0	0
24	12.9	25	0	0	0	75	0	0	0
25	32.2	60	50	10	0	40	30	20	0
26	48.4	27	13	7	7	73	47	27	27
27	48.4	40	20	13	7	60	33	28	13
28	58.1	28	22	27	6	72	50	17	11
29	64.5	40	25	15	5	60	25	10	5
30	51.6	50	25	6	6	50	18	6	0
31	48.4	47	40	27	7	53	27	7	7
32	48.4	33	27	20	0	67	7	7	0
33	51.6	63	38	25	19	37	25	19	6
34	25.8	38	38	25	25	62	50	25	0
35	41.9	46	38	31	23	54	31	0	0
36	38.7	50	42	42	42	50	0	0	0
37	29.0	89	78	56	56	11	0	0	0
38	9.7	67	67	33	33	33	0	0	0
39	12.9	75	50	25	25	25	0	0	0
40	9.7	100	67	67	67	0	0	0	0
41	6.5	100	100	100	100	0	0	0	0
42	6.5	100	100	100	100	0	0	0	0
43	6.5	100	100	50	50	0	0	0	0
44	3.2	100	100	100	100	0	0	0	0

during 29th week. Longer wet spells (W/3w) are likely only during the beginning of the monsoon period (26th and 27th week). The chances for longer dry spells (W/4D) is only 19% during the reproductive phase (after 33rd week) of crops like pulses and pearlmillet.

(iv) One-day heavy falls

The probability of occurrence of intense falls of rain is reflected in the length of the return period of the fall considered. Chow (1951) derived the following equation for return periods from 5 to 100 years :

$$X_t = \bar{X} + \sigma K_t \text{ ——————(1)}$$

where X_t = Magnitude of item with return period T.

$\bar{X}$ = Mean of extreme values

σ = Standerd deviation of the series of extreme values (one day rainfall)

K_t = Frequency factor depending on return period and length of record.

$$K_t = -\left[1.00+1.75 \log \log \left(\frac{T}{T-1}\right)\right]$$

t = Return period.

Wiess (1955) had also developed a table to know K values for various return periods for the length of the observed record of N years. By using K values from the table and incorporating it in the equation (1), expected 1-day rainfall for different return periods were calculated and presented in Table 4. It can be seen that the highest observed rainfall during the study period is more than 175 mm at all the stations, which has a return period of 10 years. Further most of the stations had recorded highest observed one-day rainfall values nearer to the estimated rainfall of 100 years return pericd except at Bhuj, Anjar and Rahapur suggesting that the chances of getting high rainfall of this amount as recorded during this century is less in the near future at these stations.

Table 4. Maximum 24 hour precipitation in mm.

Station	Maximum daily rainfall estimated by Gumbel method for return periods (years)					PMP with Km=7	Highest observed rainfall
	5	10	25	50	100		
Bhuj	140.0	180.5	232.4	270.7	308.7	585.8	467.9
Anjar	134.2	169.2	213.4	246.1	278.7	515.9	350.0
Rahapur	127.2	158.5	198.1	227.4	256.5	469.0	353.0
Bachau	130.2	160.2	198.2	226.4	254.4	458.3	257.0
Mundra	165.6	208.4	262.6	302.7	342.6	633.2	350.0
Kandla	121.7	146.5	177.8	201.1	224.2	392.5	186.2
Nalia	193.5	248.8	318.6	370.4	421.8	796.8	443.0
Mandvi	156.6	198.0	250.3	289.1	327.6	608.6	333.0
Lakhapat	170.6	225.3	294.3	345.5	396.4	767.1	388.0
Nakhatarana	139.0	174.6	219.7	253.1	[illegible]	528.1	265.2
Khavada	142.5	181.6	230.9	267.6	303.0	569.0	280.0
Khadir	119.7	142.5	171.3	192.7	213.9	368.7	177.8

Probable maximum precipitation (PMP) is also calculated for all the stations of Kutch district using the following equations as adopted by Sarma et al. (1975).

$$X_m = \bar{X} + \sigma K_m \text{ ——————— (2)}$$

where X_m = estimate of 1 day PMP

$\bar{X}$ = Mean of the events (1 day rainfall)

σ = Standard deviation of the series of extreme values.

K_m = Frequency factor

where $K_m = (\bar{X}_L - \bar{X}_{N-1}) / \sigma_{N-1}$

X_L = Largest value of the 1 day rainfall series

$\bar{X}_{N-1}$ = Mean of the events excluding the X_L values

σ_{N-1} = Standardisation of the events excluding X_L values

Using the above equation (2) after substituting the highest value of Km calculated for the widely extended district of Kutch, the PMP values were computed and included in Table 4. These values show a substantial increase on the 100 year return period values and must therefore have a very low probability of occurrence. It is very difficult to judge how realistic these values are, but they are of course the estimated upper limits to the likely samples of rainfalls.

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