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Probability estimation and rainfall variability analysis for Barmer and Jaisalmer districts of Rajasthan, India

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Abstract
The present research investigation was undertaken to work out the rainfall variability analysis at Barmer and Jaisalmer districts of Rajasthan. Daily rainfall data of 31 years (1986-2016) was used for weekly analysis to study the variability and the probability level of occurrence. The coefficient of variation and standard deviation for weekly, monthly and annual rainfall were computed for different districts. The normal onset of monsoon over different western districts of Rajasthan is between June to October. It was observed that the annual rainfall is higher at Barmer district (297.96 mm). The mean annual rainfall (214.02 mm) is lowest at Jaisalmer district and CV for the annual rainfall was examined, it was found be the least at Jaisalmer (55.77%) and highest in Barmer (58.24%).

Keywords: Daily rainfall, co-efficient of variation, standard meteorological weeks, variability, probability

Introduction
The degree to which rainfall amounts vary across an area or through time is an important characteristic of the climate of an area. This subject area in meteorology/climatology is called "rainfall variability." There are two types or components of rainfall variability, areal and temporal. The study of the latter is important in understanding climate change. The rainfall probability is an important and governing factor in the planning and operation strategies of any agricultural program for any given area. As such, proper and specific information about the rainfall distribution pattern over a period for a particular place is quite essential for proper and optimal planning of requisite irrigation system and cropping pattern. Out of 189.54 million ha (1996-97) gross cropped area (including area sown more than once) of the country, 61.3% (116.26 million ha) falls under rainfed farming. In India, the gross irrigated area has been rapidly increasing from 28 million ha in 1960-61 to 72.8 million ha in 1997-98 (DES, 2001). Despite this progress, marginal and small farmers constituting 80% of agricultural income group, still depend on rainfed farming. The early or delay in onset of monsoon, early or late withdrawal of monsoon, breaks in monsoon period, unusual heavy or no rainfall during the critical phenol-phase of crops may disturb the normal crop growth and development. To exploit the available rainfall effectively, crop planning and management practices must be followed based on the rainfall amount and distribution at a place. Archer and Fowler (2004), have studied variation of precipitation in spatial and temporal scale in the upper Indus Basin and reported that winter precipitation is highly correlated spatially across the basin and over the last century, there is no statistically significant long term trend in annual or seasonal precipitation time series. Krishnakumar *et al.* (2008) studied temporal variation in monthly, seasonal and annual rainfall over Kerala, India and revealed the significant decrease in southwest monsoon rainfall while increase in post monsoon season. Parthasarathi and Dhar (1975) reported that the rainfall over India was increased from 1431mm to 1960mm. Wadood and Kumari (2009) noticed a considerable increase in average monthly maximum rainfall pattern with high variability in recent decades in Jharkhand, India. Nandargi and Mulye (2014) studied the spatial and temporal analysis of rainfall over Jharkhand, India for the period of 100 years (1901-200). Upadhaya (2014) made an attempt to study the variability of rainfall in Rajasthan, India for the period of 50 years (1960-2009).

Material and Methods
The rainfall data for the Barmer and Jaisalmer districts of Rajasthan was taken from water resource department for period 1986-2016. The 31 years data was future used for the probability estimation and rainfall variability analysis. Time series analysis such as standard deviation, coefficient of variation and mean rainfall.

Barmer and Jaisalmer come in arid western plain and Thar Desert. The soils of this zone are predominantly Sand soil, desert soil. These are generally Sand loam in texture. The mean annual rainfall in Barmer (297.96 mm) and Jaisalmer (214.02 mm).The mean daily maximum temperature at both districts form 24.5°C in January to 45.5°C in May. Similarly the mean daily minimum temperature ranges from 8.6°C in January to 29.7°C in May. The principal crops of the zone are pear millet, cluster bean, moth bean, chick pea, wheat and fruit crop; ber, aonla, pomogrante, dateplam. Rainfall is one of the most important natural resource input to crop production in the Western region. The daily rainfall data from 1986-2016 (31 years) were collected from Department of Water Resources Government of Rajasthan. The daily rainfall was aggregated into weekly, monthly and used for the analysis. The coefficient of variation and standard deviation for weekly, monthly and annual rainfall were also computed for Barmer and Jaisalmer districts. The Incomplete Gamma Distribution Probability used for the study.

Methodology

Rainfall variability

Mean rainfall

The amount of rainfall collected by a given rain gauge in 24 hrs is known as daily rainfall (mm or cm) and the amount collected in one year in known as annual rainfall. The mean of the annual rainfall over of 35 years (in India) is known as mean annual rainfall (average annual rainfall or normal annual rainfall).

$$\text{Mean Annual Rainfall} = \frac{Total\ Rainfall}{Number\ of\ Yeras}$$

Standard Deviation (SD)

It is defined as the square root of the mean of the squares of deviations of the rainfall value from the arithmetic mean of all such rainfall. It is a measure of variability or the scatter or the dispersion about the mean value. It is given by the following formula.

$$SD\ (\sigma) = \sqrt{\frac{\sum(X-\bar{X})^2}{n-1}}$$

X = Rainfall
$\bar{X}$= Mean rainfall
n = Number of year

Coefficient of variation

Assessment of rainfall variability through Coefficient of variation (CV %) appears to be simple.

CV is defined as the Standard deviation divided by the mean value of rainfall. It shows the variability of rainfall in percentage.

$$\text{CV \%} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

The greater the CV, the lesser the dependability of receiving rainfall. Considering the annual CV, the IMD is using the following criteria for assessing the rainfall in a particular area.
Normal = - 19 to 19 % of annual normal rainfall.
Deficit = - 20 to - 59 % of annual normal rainfall.
Scarce = - 60 % and above of annual normal rainfall

Rainfall incomplete gamma probability

To analyze and estimate the rainfall incomplete gamma probability using Weather cock Software. Weather cock with version 15; Software developed by V.U.M. Rao, A.V.M.S. Rao, G.G.S.N. Rao, T. Satyanaryana, N. Manikandan, B. Venkateswarlu and I. Ramamohan in 2011 under All India Co-ordinated Research Project CRIDA, Hyderabad. It contains various modules such as-data management, data quality, daily data conversions, rainfall analysis, temperature analysis, length of growing period and water balance. Application under rainfall analysis have been found viz., agricultural drought, meteorological drought, high rainfall events, incomplete gamma probability, initial and conditional probabilities, probability of dry and wet weeks, rainy days etc. One of the important problems in hydrology, deals with interpreting a past record of rainfall events, in terms of future probabilities of occurrences. There are many probability distributions that have been found to be useful for hydrologic frequency analysis. Hence, incomplete gamma distribution (IGD) was used (Manjunath *et al*., 2014) [5]. Biswas and Khambeta (1974) and computed the lowest amount of rainfall at different probability level by fitting gamma distribution probability model to week by week total rainfall of 82 stations in dry farming tract of Maharashtra. The amount of rainfall at different probability levels (10-90 %) called assured rainfall have been computed for each standard week by fitting incomplete gamma distribution model. Tables of assured rainfall at different probability levels gets using gamma probability tool. Probability analysis of rainfall offers a better scope for predicting the minimum assured rainfall to help in crop planning in rainfed regions.

Results and Discussion

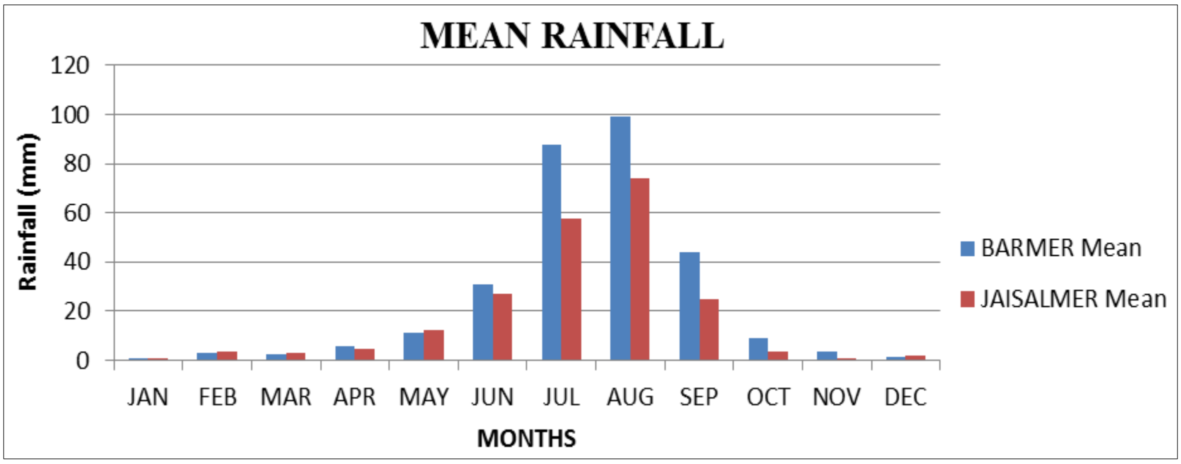
The results obtained from the present Research on Rainfall Variability, Coefficient of Variation and Incomplete Gamma Distribution have Discuses below:

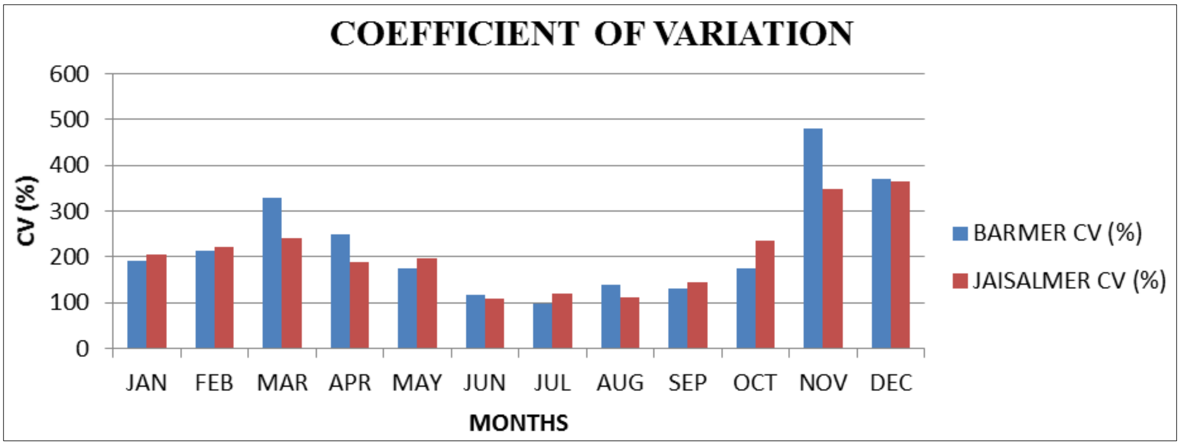
Rainfall variability

The observed mean rainfall for a period of 1986-2016 (31year) for Barmer and Jaisalmer districts. The observed mean rainfall and calculated CV and SD represent in table 1. The maximum rainfall and SD were observed in month of august 99.12 mm and 138.71 for Barmer district and 78.84 mm and 81.52 for Jaisalmer district. The maximum coefficient of variation was observed 480.72 in month of November for Barmer and 368.68% in month of December for Jaisalmer.

Table 1: Rainfall Variability in Barmer & Jaisalmer District

Month	BARMER			JAISALMER		
	Mean	SD	CV (%)	Mean	SD	CV (%)
JAN	0.70	1.34	191.43	0.80	1.65	206.25
FEB	3.13	6.67	213.10	3.47	7.66	220.75
MAR	2.50	8.19	327.60	3.27	7.85	240.06
APR	5.62	13.98	248.75	4.66	8.75	187.77
MAY	11.21	19.62	175.02	12.29	24.28	197.56
JUN	31.02	36.26	116.89	26.77	29.09	108.67
JUL	87.56	85.68	97.85	57.72	68.57	118.80
AUG	99.12	138.71	139.94	73.84	81.52	110.40
SEP	43.73	57.09	130.55	24.81	36.00	145.10
OCT	8.83	15.53	175.88	3.74	8.78	234.76
NOV	3.32	15.96	480.72	0.70	2.43	347.14
DEC	1.16	4.29	369.83	1.90	6.91	363.68
Total	297.96	173.53	58.24	214.02	119.36	55.77





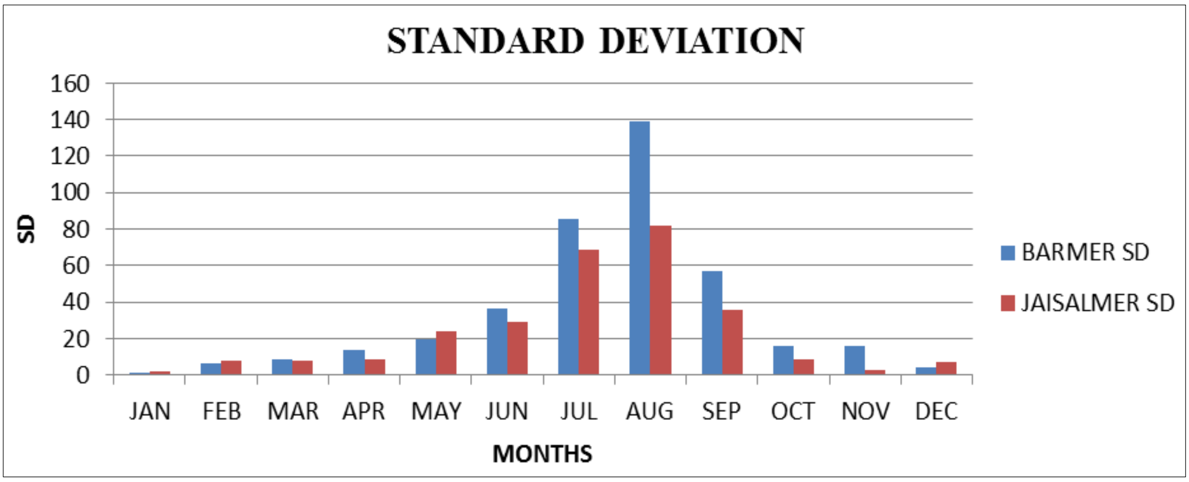


Table 2: Incomplete Gamma Distribution for Barmer & Jaisalmer District

Incomplete Gamma Distribution Precipitation (mm) for the probabilities													
	BARMER						JAISALMER						
Week	**90%**	**75%**	**50%**	**25%**	**10%**	**Mean (mm)**	**90%**	**75%**	**50%**	**25%**	**10%**	**Mean (mm)**
1	0.6	0.8	1.1	1.5	2.0	0.2	0.5	0.7	0.9	1.3	1.6	0.0
2	0.8	0.9	1.0	1.2	1.4	0.1	0.6	0.8	1.2	1.6	2.1	0.3
3	0.6	0.9	1.2	1.6	2.0	0.3	0.5	0.8	1.2	1.8	2.4	0.4
4	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.8	1.1	1.4	1.7	0.1
5	0.6	0.8	1.1	1.4	1.7	0.1	0.7	0.9	1.1	1.4	1.6	0.1
6	0.0	0.0	1.1	5.0	7.6	1.1	0.0	0.0	1.5	6.6	10.2	1.5
7	0.0	0.0	1.6	6.0	9.0	1.6	0.0	0.0	0.7	3.7	5.4	0.7
8	0.0	0.2	0.3	2.4	3.4	0.3	0.0	0.0	1.2	4.6	6.8	1.2
9	0.4	0.8	1.3	2.1	3.0	0.6	0.4	0.7	1.3	2.1	3.0	0.5
10	0.2	0.6	1.5	3.1	5.3	1.3	0.2	0.6	1.5	2.9	4.7	1.1
11	0.5	0.8	1.4	2.3	3.2	0.7	0.4	0.7	1.3	2.2	3.2	0.6
12	0.7	0.9	1.1	1.4	1.6	0.1	0.5	0.8	1.2	1.8	2.4	0.4
13	0.8	0.9	1.0	1.2	1.4	0.1	0.2	0.6	1.5	3.0	5.0	1.2
14	0.2	0.6	1.6	3.3	5.5	1.4	0.3	0.7	1.4	2.6	4.1	0.9
15	0.3	0.7	1.4	2.6	4.0	0.9	0.2	0.6	1.6	3.4	6.0	1.5
16	0.3	0.7	1.5	2.8	4.5	1.0	0.3	0.7	1.4	2.5	3.9	0.8
17	0.1	0.5	1.8	4.6	8.7	2.4	0.4	0.8	1.5	2.5	3.8	0.8
18	0.5	0.8	1.4	2.2	3.2	0.6	0.2	0.6	1.8	4.0	7.2	1.9
19	0.2	0.7	1.8	3.8	6.4	1.7	0.2	0.8	2.0	4.3	7.4	2.1
20	0.1	0.6	2.0	5.0	9.3	2.6	0.3	0.7	1.5	3.0	4.9	1.2
21	0.1	0.5	1.8	4.5	8.6	2.3	0.1	0.6	3.1	9.5	19.8	6.2
22	0.3	1.1	3.6	8.8	16.4	5.5	0.2	0.8	2.5	5.8	10.5	3.2
23	0.1	0.7	3.3	9.8	20.3	6.5	0.1	0.8	2.9	7.6	14.8	4.6
24	0.3	1.0	3.2	7.5	13.7	4.5	0.2	1.0	4.3	12.6	25.6	8.5
25	0.1	1.0	4.8	14.2	29.4	9.8	0.2	0.9	3.7	9.9	19.3	6.3
26	0.2	1.3	5.2	14.3	28.3	9.6	0.2	0.9	3.3	8.4	16.0	5.2
27	0.2	1.1	5.0	15.0	31.0	10.4	0.1	1.1	5.3	16.3	34.2	11.5
28	0.2	1.7	8.1	24.3	50.5	17.5	0.3	1.3	4.8	12.7	24.5	8.4
29	0.2	1.7	8.9	28.6	61.5	21.2	0.1	1.1	6.3	20.4	44.2	14.9
30	0.4	2.8	14.0	42.8	89.8	31.7	0.3	1.8	8.2	24.1	49.6	17.3
31	0.8	3.5	12.0	30.2	56.9	21.1	0.3	2.2	10.5	31.9	66.7	23.4
32	0.3	2.8	14.3	45.4	96.9	34.0	0.2	1.6	8.8	28.3	60.8	20.9
33	0.1	1.2	6.6	21.5	46.5	15.7	0.1	1.0	5.9	19.7	43.2	14.4
34	0.1	1.6	10.4	37.2	84.6	28.8	0.2	1.2	6.1	18.4	38.6	13.1
35	0.3	1.5	5.2	13.1	24.9	8.6	0.2	1.4	5.6	15.5	30.8	10.6
36	0.1	1.2	7.5	26.7	60.6	20.4	0.2	1.0	4.4	12.7	25.6	8.5
37	0.2	1.0	4.5	13.1	26.8	8.9	0.2	0.9	2.9	6.9	12.6	4.0
38	0.1	0.9	3.7	10.3	20.7	6.7	0.1	0.7	4.1	13.6	29.8	9.6
39	0.1	0.7	2.7	7.3	14.3	4.4	0.7	0.9	1.1	1.3	1.5	0.1
40	0.2	0.8	3.0	7.8	15.1	4.8	0.3	0.8	1.7	3.1	4.8	1.2
41	0.2	0.6	1.7	3.8	6.6	1.7	0.5	0.7	0.9	1.3	1.6	0.0
42	0.1	0.6	1.9	4.6	8.4	2.3	0.2	0.6	2.0	4.6	8.3	2.3
43	0.5	0.7	0.9	1.3	1.6	0.0	0.5	0.7	0.9	1.3	1.6	0.0
44	0.5	0.7	0.9	1.3	1.6	0.0	0.6	0.8	1.1	1.5	1.9	0.2
45	0.7	0.9	1.1	1.3	1.5	0.1	0.5	0.7	0.9	1.3	1.6	0.0
46	0.1	0.5	1.8	4.9	9.7	2.7	0.4	0.7	1.2	1.9	2.6	0.4
47	0.6	0.8	1.1	1.5	1.9	0.2	0.5	0.8	1.2	1.7	2.3	0.3
48	0.5	0.8	1.2	1.8	2.4	0.4	0.5	0.7	0.9	1.3	1.6	0.0
49	0.5	0.7	0.9	1.3	1.6	0.0	0.3	0.7	1.4	2.5	3.9	0.8
50	0.7	0.9	1.1	1.3	1.5	0.1	0.3	0.7	1.3	2.2	3.2	0.6
51	0.3	0.6	1.3	2.3	3.6	0.7	0.6	0.8	1.1	1.5	1.9	0.2
52	0.5	0.7	1.2	1.8	2.5	0.4	0.4	0.7	1.2	1.8	2.5	0.4
Annual	115.8	177.3	268.9	388.1	520.9	297.9	80.8	125.5	192.6	280.6	379.3	214.3
Data period 1986 - 2016 (31 years)												

Incomplete gamma distribution probability:

The incomplete gamma distribution probability for 52 weeks with 90%,75%,50%,25% and 10% are represent in table 2. Analysis performance at Barmer for weekly rainfall indicated that, more than 10 mm of rainfall could be expected during 30, 31, 32 and 34th SMW with 50 per cent probability (Table 2) which shows the potentiality for rain water harvesting. At 75 per cent probability at least 2 mm per week was expected during 30nd– 32nd SMW which indicates potentiality for crop growing in dry land areas. Whereas, with 25 per cent probability, the expected rainfall of more than 10 mm was observed from 22nd-38nd SMW (Table 2).

At Jaisalmer the incomplete gamma distribution probability analysis for weekly rainfall indicated that, more than 10 mm of rainfall could be expected during 31st SMW with 50 per cent probability (Table 2) which shows the potentiality for rain water harvesting. At 75 per cent probability atleast 2 mm per week was expected during 31st SMW which indicates potentiality for cropgrowing in dryland areas. Whereas, with 25 per cent probability, the expected rainfall of more than 10 mm was observed from 24th and 27th-36th SMW (Table 2). Sarkar and Biswas (1988) reported that even 30 per cent probability rainfall can be taken as weekly assured rainfall for computing moisture index if the annual rainfall is less than 400 mm.

Conclusions

The rainfall is an important and governing factor in the planning and operation strategies of any agricultural program for any given area. As such, proper and specific information about the rainfall distribution pattern over a period for a particular place is quite essential for proper and optimal planning of requisite irrigation system and cropping pattern. The major share of conjunctive water-need of the country during entire calendar year is met by the rainfall, which occurs in the monsoon period. Length of growing period is defined as the period during which the availability of moisture in the root zone of a crop is adequate to meet the water need, because the amount and distribution of rainfall varies considerably from year to year so does the effective growing period. Keeping in view the fallowing aspects the presents work "Probability Estimation and Rainfall Variability Analysis for Barmer and Jaisalmer Districts of Rajasthan, India" was conducted during different months of the data for the period (1986 - 2016) to evaluate basis on different precipitation data. The average annual rainfall for Barmer, Jaisalmer districts were found to be 297.96, 214.02 mm. The monthly values of CV during monsoon months were lower when compared to other months. However the lowest values of CV were in the month of July and August. In most of August rainfall occurred due to cyclonic activity. Annual CV value was lowest in Jaisalmer district 55.77% and highest in Barmer districts 58.24%. The probabilistic estimates of rainfall values over a short period such as weekly fortnightly and monthly, which are required to provide basic data for planning irrigation and other water resources project. This is especially true in connection with the analysis of droughts and irrigation.

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