Research Article

Statistical analysis of rainfall data

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Abstract

Rainfall, its pattern and its analysis is of interest to many researchers. To study the rainfall pattern and its various parameters data of daily rainfall of last 30 years is collected. Analysis of rainfall data depends on its distribution pattern hence the appropriate distribution is fitted for the total rainfall in a season (June to September), in weeks and in months; goodness of fit test is used to verify whether the fitted distribution is good fit or not. Using this fitted distribution the probabilities of receiving different rainfall for different periods are computed. To know whether there is significant difference in actual rainfall and normal rainfall in the months of June, July, August, and September and in a season (June to September) statistical tests are applied. Graphical representation of the rainfall in the month of September shows change in pattern after 1989; the significance of rainfall before and after 1989 is tested using statistical test. The analysis of weekly total rainfall with probability of dry spell and probabilities of weekly rainfall exceeding specific rainfall are computed.

Keywords: Rainfall, normal probability plot, t test, normal distribution, goodness of fit.

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Received Date: 18/02/2015 Accepted Date: 05/03/2015

Access this article online	
Quick Response Code:	Website: www.statperson.com
	DOI: 07 March 2015

INTRODUCTION

Indian agriculture largely depends on rainfall. Rainfall is one of the principal controlling elements in agriculture. The success of crop establishment and growth largely depends on availability of adequate rainfall in country like India. Several studies have been conducted in India and abroad on rainfall analysis. R. Srikanthan and B. J. Stewart (1991) analyzes the Australian rainfall data; they have used different statistical tests like Mann-Kendall rank correlation, Spearman rank correlation, Cumulative sum test and so on to detect the linear trend and to check whether there is change in the mean value. For weekly rainfall data two and three parameter distributions are studied by V.N. Sharda and P. K. Das (2005). They have used Anderson Darling test to test goodness of fit. Singh, Adikari and Garg (2002), Chin Yu Lee (2005), Jamaludin Suhaila and Abdul Aziz Jemain (2007) studied several types of exponential distribution and proposed mixed weibull and mixed exponential distribution. Mohita Anand Sharma and Jai Bhagwan Singh (2010) also studied several distributions and proposed a method to find out the best of the fitted distributions.

MATERIAL AND METHODS

Rainy season in India is from June to September. The daily rainfall data of Aurangabad station of last 30 years 1981-2010 was collected from meteorological observatory of Agricultural Department. The total rainfall per week for 18 weeks also total rainfall per month for the months of June, July, August and September and in seasons (June to

How to site this article: Chhaya Sonar. Statistical analysis of rainfall data. *International Journal of Statistika and Mathemtika* Feb. to Apr. 2015; 13(2): 37-42. http://www.statperson.com (accessed 10 March 2015).

September) is calculated. To study instability in rainfall coefficient of variation is studied. Coefficient of skewness is also studied, since skewness to the left indicates higher probability of failure of rainfall which is riskier situation than skewness to the right. However, the coefficient of skewness does not throw much light when the distribution has no peak or has several peaks or is generally flat. Normal distribution is fitted to the data. Kolmogorov Smirnov test is applied to test goodness of fit. While analyzing the data there are certain question such as whether the amount of rainfall is significantly same as the normal rainfall? This is verified using one sample t test. Another question is – is the total amount of rainfall is same or is it decreased or increased significantly in the last 10 years as compared to last 30 years? This is verified using two sample t test.

RESULTS AND DISCUSSION

The summary of Statistics- mean Standard deviation, coefficient of skewness, coefficient of variation at Aurangabad, Maharashtra, India is given in Table 1.

Table 1: Summary statistics of rainfall (1981- 2011) at Aurangabad station

Study Period	Mean	Standard Deviation	*Skewness Coefficient	Coefficient of variation
Season	794.00	211.06	3.22	32.32
June	135.01	88.80	2.50	65.77
July	161.43	70.10	2.74	43.43
August	151.74	80.80	2.30	53.25
September	169.84	131.36	2.04	77.35
1st week(2 to 8 June)	17.11	26.24	1.48	153.34
2nd week(9 to 15 June)	49.06	52.02	1.87	106.03
3rd week(16 to 22 June)	25.45	20.95	1.59	82.30
4th week(23 to 29 June)	32.40	29.54	1.46	91.16
5th week(30 June to 6 July)	31.57	29.98	1.08	94.96
6th week(7 to 13 July)	27.24	28.51	1.35	104.64
7th week(14 to 20 July)	33.83	30.80	1.41	91.03
8th week(21 to 27 July)	31.42	30.18	1.31	96.04
9th week(28 July to 3 Aug)	34.44	41.34	1.50	120.03
10th week(4 to 10 Aug)	41.66	43.37	1.30	104.11
11th week(11 to 17 Aug)	51.31	104.17	1.10	203.01
12th week(18 to 24 Aug)	29.68	26.60	1.60	89.62
13th week(25 to 31 Aug)	33.31	40.45	1.20	121.44
14th week(1 to 7 Sep)	49.37	64.29	1.34	130.24
15th week(8 to 14 Sep)	25.38	27.28	1.54	107.49
16th week (15 to 21 Sep.)	30.97	44.82	1.37	144.73
17th week (22 to 28 Sep.)	42.37	39.60	1.16	93.46

*The coefficient of skewness is calculated on the basis of actual observations for every year and then the average of all 30 years is given in Table 1.

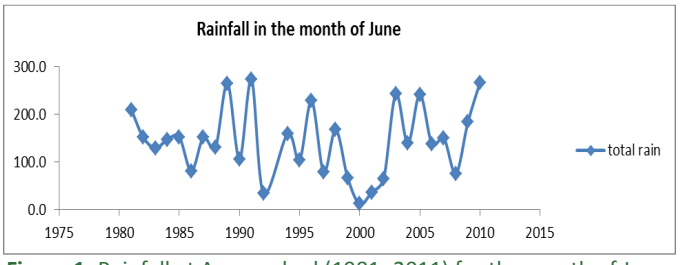

Figure 1: Rainfall at Aurangabad (1981- 2011) for the month of June

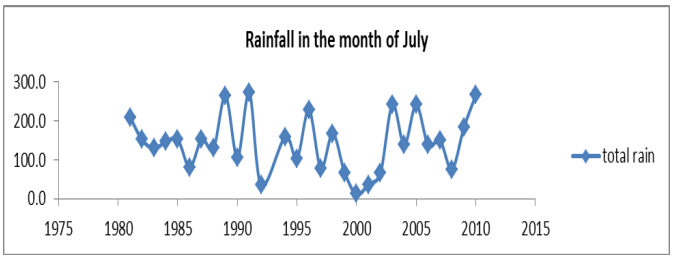

Figure 2: Rainfall at Aurangabad (1981- 2011) for the month of July

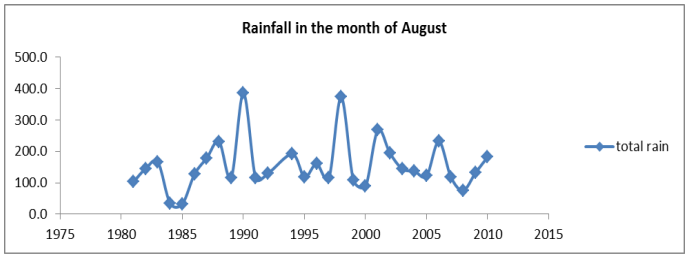

Figure 3: Rainfall at Aurangabad (1981- 2011) for the month of August

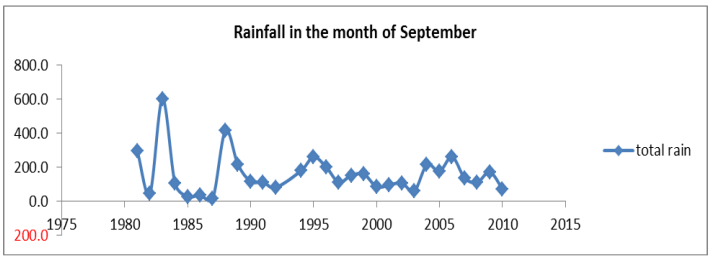

Figure 4: Rainfall at Aurangabad (1981- 2010) for the month of September

Graphical representation of the total rainfall (figure 1- 4) in the month of September indicates that there is noticeable change in the rainfall pattern from year 1990. The coefficient of variation of rainfall from 1981 to 1989 is 94.29% with average rainfall 206.844 mm and for the period 1990 to 2010 it is 60.09% with average rainfall 153.19 mm this shows that though the rainfall after year 1989 is more consistent there is noticeable decrease of rainfall in the month of September. To check the significance of the equality in the total amount of rainfall till 1989 and after 1989 two sample t test ($H_0 : \mu_1 = \mu_2$) is generally used but for rainfall data since the variation is large it is necessary to validate the equal variance assumption; to check the equal variance assumption F test is used.

The output using MINITAB 14 is given below:

F-Test (normal distribution)

Test statistic = 0.11, p-value = 0.000

It indicates that there is significant difference in variances of the total amount of rainfall till 1989 and after 1989. Therefore two sampled t test cannot be used to test $H_0 : \mu_1 = \mu_2$ this is referred as Behrens-Fisher problem. In this situation the Welch approximate t test is used. This test indicates that the difference in means for 1981-1989 and after 1989 (1990- 2010) is not significant. To check the significance of rainfall as compared to the normal rainfall in the months of June (134 mm), July (169.3), August (156.5) and September (163.5) one sample t test is used to apply t test the data is to follow normal distribution. To check the normality, normal probability plots are used; the normal probability plot for the month of July is given in fig.5

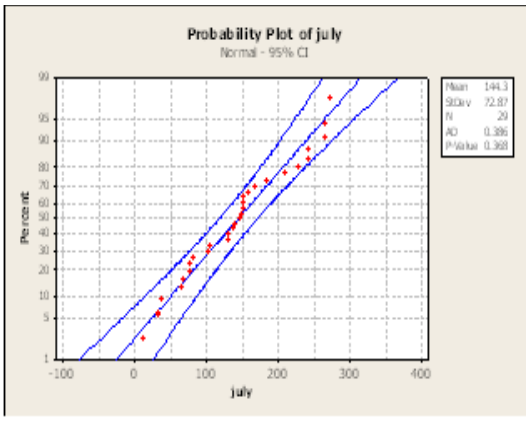

Figure 5: Normal probability plot of the month of July

To check the significance of expected normal rainfall one sample t test using MINITAB software is executed, the output of the test is given below:

One-Sample T: july

Test of mu = 169.3 vs not = 169.3

Table 1:

Variable	N	Mean	St Dev	SE Mean	95% CI	T	P
July	29	144.334	72.869	13.531	(116.616, 172.052)	-1.85	0.076

The output indicates that the expected normal rainfall in the month of July is not significantly different than 169.3. The same procedure is followed for the months of June, August and September and it is observed that the actual rainfall is same as the expected rainfall.

Fitting of Normal Distribution

Normal distribution is fitted to the data; the estimated parameters are given in the following Table 2. Kolmogorov Smirnov test is used to test the goodness of fit of the fitted distribution; value of Kolmogorov Smirnov test statistic is also listed in the Table 2.

Table 2: Parameters of the fitted Normal distribution

Period	Parameters		Kolmogorov Smirnov	Rainfall >	Probability of column (5)
(1)	μ (2)	σ^2 (3)	test Statistic (4)	(5)	(6)
Season	658.435	208.961	0.027	600 mm	0.6101
June	132.185	90.5768	0.0821	110 mm	0.5535
July	154.666	73.462	0.0019	140 mm	0.6815
August	152.187	79.4286	0.0304	126 mm	0.6573
September	179.943	140.444	0.0049	145 mm	0.6652
1st week(2 to 8 June)	13.434	19.1807	0.0496	10mm	0.571
2nd week(9 to 15 June)	46.279	68.3123	0.0297	10mm	0.7023
3rd week(16 to 22 June)	26.8157	31.182	0.0313	10mm	0.7052
4th week(23 to 29 June)	37.0397	39.0919	0.0332	10mm	0.7554
5th week(30 June to 6 July)	28.274	32.0731	0.0309	10mm	0.7156
6th week(7 to 13 July)	19.5597	20.8614	0.0329	10mm	0.6766
7th week(14 to 20 July)	36.261	33.9479	0.0331	10mm	0.7804
8th week(21 to 27 July)	39.4507	36.9448	0.0216	10mm	0.7873
9th week(28 July to 3 Aug)	32.8357	34.0207	0.0327	10mm	0.749
10th week(4 to 10 Aug)	50.4293	52.4409	0.0323	10mm	0.7796
11th week(11 to 17 Aug)	39.7507	39.2918	0.0323	10mm	0.7755
12th week(18 to 24 Aug)	26.663	31.6515	0.022	10mm	0.7007
13th week(25 to 31 Aug)	31.267	38.1478	0.0257	10mm	0.7114
14th week(1 to 7 Sep)	54.8787	71.8919	0.0055	10mm	0.7338
15th week(8 to 14 Sep)	38.4803	50.8272	0.0021	10mm	0.7124
16th week (15 to 21 Sep.)	42.7153	59.356	0.0131	10mm	0.7092
17th week (22 to 28 Sep.)	46.5667	43.8301	0.0184	10mm	0.7979

18th week (29 Sep. to 5 Oct.)	48.4047	90.3428	0.0239	10mm	0.6646

Fitted distributions can be used to estimate probabilities like normal seasonal rainfall of Aurangabad is 752 mm hence one can compute probability of seasonal rainfall exceeding 600mm, 650 mm and so on or vice versa rainfall less than any value. Some such specific probabilities of rainfall exceeding the rainfall given in column 5 are listed in column 6 of Table 2.

Table 3: Summary Statistics of Weekly Rainfall

Seasonal week (1)	Period (2)	Avg. No. of rainy days (3)	Average rainfall in mm (4)	Probability of dry spell (5)
1	2 to 8 June	1	13.88	0.40
2	9 to 15 June	3	45.70	0.33
3	16 to 22 June	3	27.12	0.27
4	23 to 29 June	3	37.71	0.17
5	30 June to 6 July	3	26.70	0.13
6	7 to 13 July	3	18.83	0.13
7	14 to 20 July	4	37.47	0.10
8	21 to 27 July	4	38.49	0.00
9	28 July to 3 Aug.	4	33.12	0.20
10	4 to 10 Aug.	4	49.92	0.07
11	11 to 17 Aug.	4	40.77	0.03
12	18 to 24 Aug.	3	26.61	0.13
13	25 to 31 Aug.	3	32.31	0.33
14	1 to 7 Sep.	3	54.51	0.40
15	8 to 14 Sep.	3	36.23	0.23
16	15 to 21 Sep.	2	40.34	0.20
17	22 to 28 Sep.	3	47.76	0.37
18	29 Sep. to 5 Oct.	2	48.67	0.33

In table 3 the probabilities are computed using the fitted normal distribution with corresponding parameters as enlisted in column 2 and 3 of Table 2. The distribution of rainfall in corresponding weeks becomes clearer from the average number of rainy days and total rainfall during the period given in table 3 they gives idea of rainfall or availability of water for the crops during corresponding period.

CONCLUSION

i. The monthly rainfall of June, July, August and September do not differ significantly from specified average monthly rainfall of Aurangabad station.

ii. From the graphical representation given in Fig.4 there is a question whether the rainfall pattern changes after 89? To clarify this doubt Welch approximate t test is used; but there is no significant change in monthly rainfall before 89 and after 89.

iii. From table 2, probability of getting 600mm rainfall in a season is 0.6101. Probability of getting 110mm, 140mm, 126mm and 145mm rainfall in the month of June, July, August and September are 0.5535, 0.6815, 0.6573 and 0.6652 respectively. One can find the probabilities of required rainfall for any period and minimum rainfall required for the crop in corresponding period and plan accordingly.

iv. From Table 3 from seasonal week 2 (9 to 15 June) the chance of receiving minimum 10 mm rainfall is 73% and in subsequent weeks till 10^{th} seasonal week the chances are more than 70%. That is for a period of 8 weeks the chances of assured rainfall are higher than 70% in subsequent two weeks the chances are more than 60 % and the rainfall values more than 60 % probability are considered as reliable for cropping, also the probability of dry spell is less during this period. From the last week of August there are comparatively less chances of receiving rainfall exceeding 10 mm and the probability of dry spell is also increasing in the subsequent weeks. Hence as per requirement of the crop, the various agricultural operations should be planned to get maximum yield.

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Source of Support: None Declared
Conflict of Interest: None Declared