Agriculture for Sustainable Development 1(1):95-102, 2013/Review *ISSN 2347-5358 (Print)*

Agriculture for Sustainable Development

http://www.sustainableagriculture.in

STATISTICAL AND PROBABILITY ANALYSIS OF RAINFALL FOR CROP PLANNING IN A CANAL COMMAND

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Received: 09.10.2013 **Revised accepted: 23.11.2013**

ABSTRACT

In the present study, statistical and probability analysis of 40 years daily rainfall data for the period 1971-2010 were carried out on weekly, monthly and annual basis. Rainfall pattern in the area is also analyzed using *thiessen* polygon and Histogram technique. Probability analysis was done using two and three parameters probability distribution functions. The best distribution representing the command was identified using *Chi-squared* (χ^2) test at different probability level. Amongst the nine distributions fitted in the Tawa canal command, Log-normal distribution and Weibull distribution (2) are found as the best fit distribution for annual and monthly rainfall data respectively. When the distributions depicting standard monsoon and non-monsoon weeks in the region are studied, it has been found that Beta and Weibull represents best in comparison to other distributions. Finally, the best fit distribution is employed for computing the minimum assured amount of rainfall at different probability levels for the command area.

Keywords:
Goodness-of-fit, *Chi-squarer (χ^2) test*, Probability distribution, rainfall, statistical analysis

INTRODUCTION

India is an agrarian country with about 60% of the cultivated area under rain-fed conditions and the remaining 40% under irrigated area. Rain-fed agriculture supports 40% of the population and 60% of the livestock in the country (NRAA, 2011). Rainfall and its distribution in the country are erratic in nature. There is high temporal and regional variation of rainfall in the country. India receives rainfall mainly from two fronts viz. south-east monsoon and south-west monsoon concentrating in the months of June to September. Almost 80% of the total rainfall is being received within 100 hours distributed in those months. DES, 2011 report suggests a highest overall rainfall variation of 18.6% in the year 2002-03. During the same period monsoon rainfall declines to 19.2% in comparison to rainfall received during the last two decades. Therefore, among other factors, rainfall (monsoon) plays an important role on nation's growth and economy in particular. Also, rainfall is one of the most important inputs to crop production. Hence, understanding the underlying processes describing the rainfall pattern, distribution and availability in a region is the first step before planning further. The inference from the analyzed rainfall data can be utilized in number of ways such as identifying dry spell, developing drought indices, estimating flood, etc.

It is the rainfall distribution which affects the yield in a region rather than the volume of rainfall received (Fisher, 1924). Probability and frequency analysis of rainfall data enables us to determine the expected rainfall at different probability level. Rainfall at 80 per cent probability can be taken as assured rainfall, while the median value (50 per cent) as the maximum limit for taking any risks (Gupta *et al*., 1975). At below 50 per cent, if considered, chances of crop failure will be high. Many similar studies by different researchers worldwide have undertaken for regional crop planning through analyzing rainfall data. Nemichandrappa *et al*. (2010) analyzed 30 years rainfall data in the semi-arid zone of Raichur, Karnataka. Probability analysis of daily rainfall data using 2-parameters and 3-parameters probability distribution and concluded that Gumbel distribution suits the best for the region. Sharma and Singh (2010) analyzed daily rainfall data for 37 years collected from the IMD approved observatory at GB Pant University of Agriculture and Technology, Pantnagar, India. The data were analyzed fitting distributions and Goodness-of-fit for those distributions were performed using three statistical test viz. Kolmogorov-Smirnov test, Anderson-Darling test and Chi-Squared Test. Mokashi *et al*. (2008) analyzed 30 years daily rainfall data collected from Dry Farming Research Station, Solapur, India and studied the probability distribution of rainfall for the monsoon weeks for crop system planning based on the rainfall distribution. Bhakar *et al*. (2008) made a detailed statistical analysis of weekly and monthly rainfall data using 35 years daily rainfall data. In the study different density functions were tried to identify the best fit distribution

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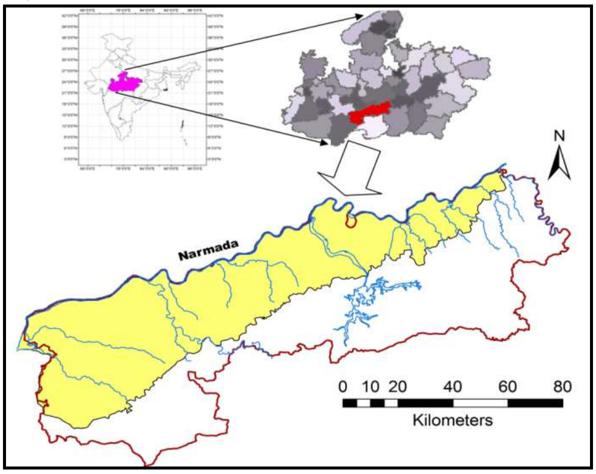
generalizing the Kota region in India. Baskar *et al*., (2006) observed the frequency analysis of consecutive days peaked rainfall at Banswara, Rajasthan, India, and found gamma distribution as the best fit as compared to other distributions using by Chi-squared test. NIH (1998) extensively studied the rainfall series to identify any trend and persistence in the Sagar division, Madhya Pradesh. The study indicated a poor serial correlation with no persistence. The rainfall series described a normal distribution in the region. Upadhaya and Singh (1998) predicted rainfall using various probability distributions for certain returns period. Biswas and Khambete (1989) computed rainfall at different probability level by fitting gamma distribution considering weekly data from 80 stations in the state of Maharashtra, India. Ramasastri and Nirupama (1986), carried out statistical analysis of monthly and annual rainfall data of Belgaum district to identify the presence of trend and to study low rainfall pattern in the region. Kulandaivelu (1984) undertaken daily rainfall data for 70 years for the Coimbatore region in the state of Tamilnadu and analysed the daily precipitation data by fitting Gamma distribution model. Virmani *et al*. (1982) carried out analysis of the rainfall probabilities for 77 semi-arid locations of the Indian sub-continent. The analysis was done on weekly basis utilizing Markov Chain probabilities. RamaRao *et al*., (1975) analyzed the daily rainfall data for the period 1921 to 1970 at Bijapur.

Asian summer monsoon has been investigated for variability using Climate System Model, version 1.4. Simulation analysis indicated that a stronger monsoon is being favoured by the large-scale warm temperature. Ashkar and Mahdi (2003) investigated generalized probability weighted moments (GPWM) and maximum likelihood (ML) fitting methods in the two-parameter log-logistic (LL) model. Probable Maximum Precipitation (PMP) often need in planning and designing multi-purpose reservoirs. Papalexiou and Koutsoyiannis (2006) estimated the PMP and analyzed the results using probabilistic approach for the data collected from 4 stations. Durbude (2008) estimated PMP for planning soil and water conservation structures in the Banswara district of Rajasthan, India. Weerasinghe (1989) analyzed 35 years consecutive rainfall data using Markov Chain probabilities for weekly rainfall. Rainfall availability in the region was assessed for crop planning.

MATERIALS AND METHODS

Study area

Tawa command is distributed in an area of about 5273.12 km^2 falling in the district of Hoshangabad, Madhya Pradesh. It lies between north latitude from 22º54’ to 23º00’ N and longitude from 76º457’ to 78º45’ E. The area is characterized by a hot summer and evenly distributed rainfall during the southwest monsoon period. The temperature starts rising from beginning of February and peak is reached in the month of May 42ºC. The winter season commences with November and December is the coolest month with temperature 7.2 ºC. The relative humidity during summer is low in the month of April i.e. about 18.1% and is maximum in August i.e., 86.7%. The average annual rainfall based on observations recorded during 1971 to 2010 is 1174.78 mm. The location map of the study area is shown in Fig.1.



Data used

The daily rainfall data were collected from India Meteorological Department (IMD), Pune for 40 years from 1971 to 2010. Daily rainfall data were also collected from the fourteen local stations spread over in and around the Tawa command area from the State Data Centre, Bhopal, Madhya Pradesh. The daily data were converted to weekly and monthly rainfall.

Probability distributions for rainfall data analysis

The probability distribution of both 2-parameters and 3-parameters were considered to indentify the best fit probability distribution for the region. The description of each distribution type with its range and shape factors is presented in Table 1.

RESULTS AND DISCUSSION

Percentage variation in actual and normal rainfall received in area

The study started with analyzing rainfall data during the period 1992-93 to 2010-11 to recognize any variation in the overall annual and monsoon rainfall in the region. As presented in Table 2 that a large variation (both increasing and decreasing) is seen both during monsoon rainfall (Jun-Sept) and overall rainfall (Jun-May). The percentage variation is highest in the year 2002-03 when the rainfall received in the district declined considerably. Tawa command falls in the central part of India. It is also revealed from Table 2 that the command area also witnesses considerable percentage variation particularly during monsoon. The year-wise percentage variation during 1992-93 to 2010-11 is also shown graphically in Fig.2.

Table 1: Description of Probability Density Functions considered in the study

Distribution type	Probability Density Function	Range	Parameters
Normal	$f(x) = \frac{\exp[\frac{1}{2}(\frac{x-\mu}{\sigma})^2]}{\sigma\sqrt{2\pi}}$	$-\infty < x < +\infty$	μ = Mean σ = Standard deviation (>0)
Log-normal	$f(x) = \frac{\exp[\frac{1}{2}(\frac{\ln x-\mu}{\sigma})^2]}{x\sigma\sqrt{2\pi}}$	$0 < x < +\infty$	μ = Mean σ = Standard deviation (>0)
Gumbel Min	$f(x) = \frac{\exp[(\frac{x-\mu}{\sigma}) - \exp(\frac{x-\mu}{\sigma})]}{\sigma}$	$-\infty < x < +\infty$	μ = Mean σ = Standard deviation (>0)
Gumbel Max	$f(x) = \frac{\exp[-(\frac{x-\mu}{\sigma}) - \exp(\frac{x-\mu}{\sigma})]}{\sigma}$	$-\infty < x < +\infty$	μ = Mean σ = Standard deviation (>0)
Weibull (2)	$f(x) = \frac{\alpha}{\beta}(\frac{x}{\beta})^{\alpha-1}\exp[(\frac{x}{\beta})^{\alpha}]$	$\gamma \le x < +\infty$	α = Shape parameter (α>0) β = Scale parameter (β>0)
Gamma (2)	$f(x) = \frac{x^{\alpha-1}}{\beta^{\alpha}\Gamma(\alpha)}\exp(-\frac{x}{\beta})$	$0 < x < +\infty$	α = Shape parameter β = Scale parameter Γ = Gamma function
Beta	$f(x) = \frac{1}{B(\alpha_1,\alpha_2)}\frac{(x-a)^{\alpha_1-1}(x-b)^{\alpha_2-1}}{(b-a)^{\alpha_1+\alpha_2-1}}$	$a < x < b$	α_1 = Shape parameter α_2 = Shape parameter B = Beta function
Log- Pearson (3)	$f(x) = \frac{1}{x\lvert\beta\rvert\Gamma(\alpha)}(\frac{\ln(x)-\gamma}{\beta})^{\alpha-1}\exp(-\frac{\ln(x)-\gamma}{\beta})$	$0 < x \le e^{\gamma}$ (β<0) $e^{\gamma} \le x < +\infty$ (β>0)	α = Shape parameter (α>0) β = Scale parameter (β>0) γ = Location parameter
Gamma (3)	$f(x) = \frac{(x-\gamma)^{\alpha-1}}{\beta^{\alpha}\Gamma(\alpha)}\exp(-\frac{(x-\gamma)}{\beta})$	$\gamma < x < +\infty$	α = Shape parameter β = Scale parameter Γ = Gamma function
Weibull (3)	$f(x) = \frac{\alpha}{\beta}(\frac{x-\gamma}{\beta})^{\alpha-1}\exp[(\frac{x-\gamma}{\beta})^{\alpha}]$	$\gamma \le x < +\infty$	α = Shape parameter (α>0) β = Scale parameter (β>0) γ = Location parameter

Table 2: Rainfall variation during 1992-93 to 2010-11 for Monsoon, Overall and Central part of India

Year	Monsoon rainfall (mm) (June-Sept)			Overall rainfall (mm) (June-May)			Monsoon rainfall in Central India (mm) (June-Sept)		
	Actual	Normal	% variation	Actual	Normal	% variation	Actual	Normal	% variation
1992-93	830.7	899.2	-7.6	1091.6	1175.6	-7.1			
1993-94	902.1	908.9	-0.7	1184.3	1192.6	-0.7			
1994-95	999.2	906.8	10.2	1297.3	1190.7	9.0			
1995-96	904.5	904.7	0.0	1154.6	1189.3	-2.9			
1996-97	927.6	905.7	2.4	1195.5	1190.3	0.4			
1997-98	927.4	908.6	2.1	1291.5	1198.3	7.8			
1998-99	945.2	903.6	4.6	1275.5	1198.8	6.4			
1999-00	866.9	903.2	-4.0	1183.5	1197.0	-1.1			
2000-01	833.7	902.3	-7.6	1043.7	1195.5	-12.7			
2001-02	826.0	901.1	-8.3	1120.2	1196.0	-6.3			
2002-03	737.1	911.7	-19.2	981.4	1205.4	-18.6			
2003-04	947.3	902.7	4.9	1278.0	1196.5	6.8			
2004-05	779.6	893.3	-12.7	1085.9	1197.3	-9.3	1094.9	993.2	10
2005-06	879.3	892.5	-1.0	1185.4	1196.8	-1.0	1152.2	993.9	16
2006-07	886.6	892.2	-0.6	1133.0	1195.5	-5.2	1073.8	993.9	8
2007-08	936.9	892.2	5.0	1180.2	1194.8	-1.2	956.9	993.9	-4
2008-09	873.2	892.2	-2.1	1075.0	1196.4	-10.1	794.8	993.9	-20
2009-10	689.8	892.2	-22.7	972.8	1195.6	-18.6	1027.9	991.5	4
2010-11	912.8	893.2	2.2	1212.3	1191.7	1.7			

Source: DES, 2011

Thiessen polygon showing spatial pattern of rainfall received in area

Thiessen polygon (Voronoi diagram) provides the area of influence of each gauge station in and around the study area. The perpendicular bisector of each line joining two stations generates the area of influence (polygon). Once the area of influence (thiessen weight) is assessed for individual stations, average rainfall received in the area is estimated using the following equation:

$$\bar{P} = \sum_{i=1}^{N}(P_1A_1 + P_2A_2 + \dots + P_NA_N)/A$$

(1)

Where,

$\bar{P}$ = Average rainfall; P_N = Rainfall for individual station; A_N = Area of influence (Thiessen weight) for individual station; A = Total area. The average rainfall received in the area using Thiessen polygon is 1036.18 mm as presented in Table 3.

Table 3: Station-wise average rainfall and corresponding Thiessen weight

Sl. No.	Station	Latitude	Longitude	Aavg. rainfall	Thiessen weight (km^2)	Thiessen average
1	Babai	22.704167	77.931667	923.97	554.934	512742.37
2	Bankhedi	23.775000	78.541667	1176.15	41.1951	48451.62
3	Harda	22.345833	77.093333	1051.66	972.866	1023124.26
4	Hoshangabad	22.750556	77.720833	1197.48	332.578	398255.50
5	Itarsi	22.611111	77.775000	1148.30	435.273	499823.99
6	Khirkia	22.170833	76.860000	828.35	714.403	591775.73
7	Pipariya	22.751667	78.357222	1054.50	235.634	248476.05
8	Seoni Malwa	22.454167	77.470000	1172.91	862.903	1012107.56
9	Sohagpur	22.705556	78.202778	987.84	368.478	363997.31
10	Timarani	22.377778	77.230556	1013.62	754.863	765144.23
		∑		**10554.78**	**5273.1271**	**5463898.61**

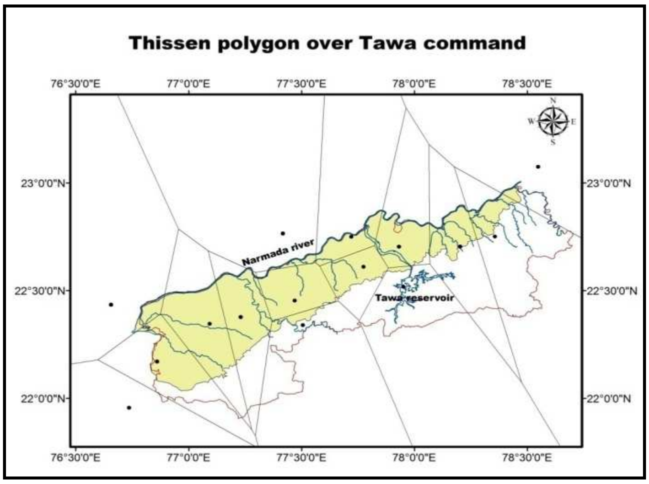


Fig. 2 Thissen polygon drawn utilizing the local stations is shown.

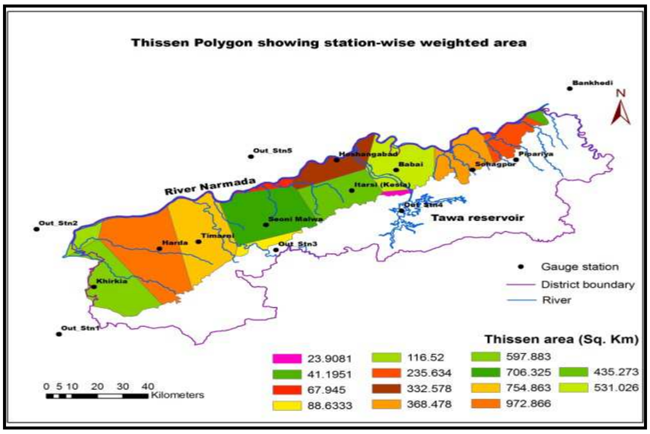


Fig.3. Thiessen polygon over Tawa command

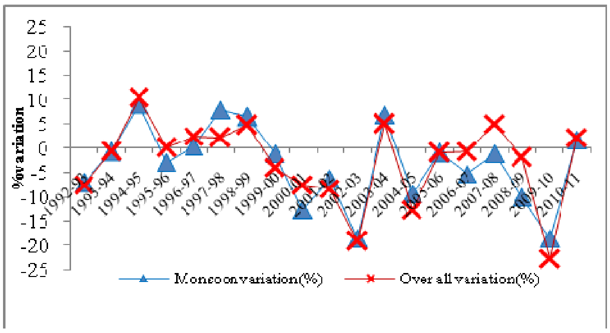


Fig.2. Rainfall variation during the period 1992-93 to 2010-11

Histogram showing range of rainfall with corresponding events

Histogram is a representation of frequency of occurrence of any event in an experiment. When the annual mean rainfall data is analyzed to assess the frequency of occurrence of a particular rainfall amount, it is found that 75% of the rainfall events are in the range of 751 mm to 1500 mm. Extreme rainfall with more than 1501 mm is also witnessed in 17.5% of the rainfall events occurring in the command area. The histogram of rainfall is shown in Fig.4.

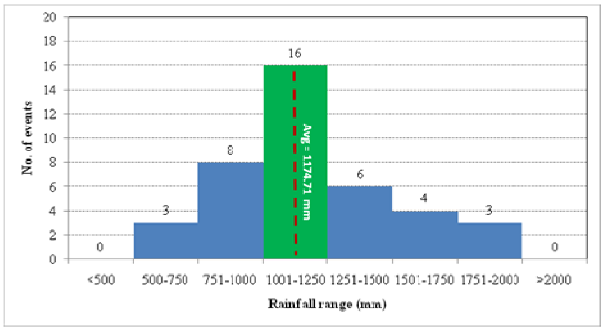


Fig.4. Histogram of rainfall for the period 1971-2010

Statistical analysis of rainfall for the period 1971-2010

The summery of statistical mean (μ), standard deviation (σ), variance (σ^2), coefficient of variation (C_v) and coefficient of skewness (Ck) for weekly, monthly, and annual rainfall for 40 years (1971-2010) is presented in Table 4, Table 5 and Table 6 respectively. The mean rainfall in the Tawa command for all years annually is 1174.78 mm, monthly is 97.98 mm and weekly is 22.59 mm. Mean monthly rainfall varies from 0.83 mm in the month of April to 404.27 mm in the month of July. Whereas, mean weekly rainfall varies from 0.06 mm in the SW 16 to 97.94 mm in the SW 33. The weekly coefficient of variation suggested that the variation is maximum during the standard monsoon weeks (SW 26 to SW 37) indicating fluctuating rainfall pattern in the region. Similar trend is also seen for the four monsoon month's viz. June, July, August and September indicating atmospheric instability during monsoon. Minimum value of standard deviation is 2.74 during April and 0.16 during SW 16. It indicates better weather stability in the period.

Table 4: Statistical analysis of weekly rainfall for the period 1971-2010

Weekly rainfall analysis for the period 1971-2010 (Tawa region)						
SW	Total	Mean (μ)	SD (σ)	Variance (σ^2)	Coefficient of variation (C_v)	Coefficient of skewness (Ck)
1	7.23	0.18	0.55	0.30	0.02	3.50
2	101.49	2.54	7.71	59.50	0.34	3.03
3	18.04	0.45	1.36	1.84	0.06	3.56
4	71.95	1.80	10.14	102.82	0.45	6.28
5	40.01	1.00	3.75	14.04	0.17	4.60
6	110.06	2.75	7.14	51.00	0.32	3.09
7	14.36	0.36	0.84	0.71	0.04	2.38
8	34.00	0.85	4.10	16.78	0.18	5.46
9	54.28	1.36	4.14	17.16	0.18	3.79
10	99.25	2.48	8.86	78.52	0.39	5.00
11	55.54	1.39	5.01	25.10	0.22	3.96
12	1.66	0.04	0.26	0.07	0.01	6.32
13	21.01	0.53	2.22	4.93	0.10	5.17
14	5.99	0.15	0.60	0.36	0.03	4.75
15	18.77	0.47	2.66	7.06	0.12	6.21
16	1.00	0.03	0.14	0.02	0.01	6.20
17	3.94	0.10	0.39	0.15	0.02	4.34
18	5.95	0.15	0.59	0.35	0.03	5.56
19	10.51	0.26	0.68	0.46	0.03	2.95
20	97.88	2.45	7.96	63.39	0.35	4.32
21	45.06	1.13	3.86	14.89	0.17	5.56
22	142.82	3.57	8.44	71.17	0.37	3.23
23	480.28	12.01	17.74	314.65	0.79	1.60
24	1194.18	29.85	48.14	2317.15	2.13	2.39
25	1806.12	45.15	44.31	1963.17	1.96	1.68
26	3665.50	91.64	126.64	16036.79	5.61	3.70
27	2943.26	73.58	78.63	6182.68	3.48	1.44
28	3422.48	85.56	69.12	4777.35	3.06	0.89
29	2342.16	58.55	85.52	7313.38	3.79	3.08
30	3257.04	81.43	93.94	8824.06	4.16	1.99
31	3131.03	78.28	75.55	5707.74	3.34	1.60
32	3511.01	87.78	64.06	4103.79	2.84	1.34
33	3917.67	97.94	106.68	11380.01	4.72	1.83
34	3896.47	97.41	75.76	5739.51	3.35	0.74
35	3714.33	92.86	97.35	9476.05	4.31	1.47
36	2613.57	65.34	72.23	5217.77	3.20	1.22
37	2190.53	54.76	95.58	9135.68	4.23	2.83
38	1247.00	31.17	41.25	1701.93	1.83	2.12
39	842.18	21.05	31.53	994.09	1.40	1.47
40	470.38	11.76	19.73	389.17	0.87	2.20
41	267.30	6.68	18.16	329.79	0.80	4.61
42	110.43	2.76	9.04	81.76	0.40	4.48
43	129.44	3.24	18.13	328.66	0.80	6.25
44	93.91	2.35	11.04	121.89	0.49	5.80
45	118.56	2.96	11.27	126.97	0.50	4.33
46	118.13	2.95	10.69	114.29	0.47	4.14
47	76.39	1.91	9.15	83.65	0.40	5.95
48	167.24	4.18	20.11	404.53	0.89	6.06
49	184.07	4.60	25.07	628.69	1.11	6.26
50	12.53	0.31	1.27	1.61	0.06	4.77
51	55.05	1.38	6.51	42.40	0.29	5.73
52	51.99	1.30	6.38	40.72	0.28	5.67

Weekly analysis								
Mean	Max	Min	SD_{max}	SD_{min}	C_{vmax}	C_{vmin}	C_{kmax}	C_{kmin}
22.59	97.94 (SW33)	0.03 (SW16)	126.64 (SW26)	0.14 (SW16)	5.61 (SW26)	0.01 (SW12)	6.32 (SW12)	0.74 (SW34)

Table 5: Statistical analysis of weekly rainfall for the period 1971-2010

Monthly rainfall analysis for the period 1971-2010 (Tawa region)						
Months	Total	Mean (μ)	SD (σ)	Variance (σ^2)	Coefficient of variation (C_v)	Coefficient of skewness (Ck)
Jan	230.89	5.77	15.59	243.00	0.16	3.92
Feb	181.08	4.53	8.29	68.78	0.08	2.11
Mar	213.55	5.34	13.94	194.30	0.14	3.88
Apr	33.07	0.83	2.74	7.53	0.03	5.30
May	250.75	6.27	14.79	218.88	0.15	3.67
Jun	6798.40	169.96	147.32	21703.55	1.50	2.15
Jul	13237.06	330.93	180.34	32521.08	1.84	0.83
Aug	16170.77	404.27	179.48	32214.34	1.83	0.93
Sep	8022.83	200.57	179.20	32114.32	1.83	1.41
Oct	1061.14	26.53	35.73	1276.79	0.36	1.64
Nov	467.12	11.68	27.12	735.72	0.28	2.88
Dec	324.34	8.11	26.65	710.47	0.27	5.22

Monthly analysis								
Mean	Max	Min	SD_{max}	SD_{min}	C_{vmax}	C_{vmin}	C_{kmax}	C_{kmin}
97.90	404.27 (Aug)	0.83 (Apr)	180.34 (Jul)	2.74 (Apr)	1.84 (Jul)	0.03 (Apr)	5.30 (Apr)	0.83 (Jul)

Table 6: Statistical analysis of annual rainfall for the period 1971-2010

Yearly rainfall analysis for the period 1971-2010 (Tawa region)					
Mean	Max	Min	SD_{max}	C_v	C_k
1174.78	1897.67 (2003)	651.81 (2000)	302.04	0.26	0.59

Table 7: Probability analysis of monthly rainfall series for the period 1971-2010 using Chi-squared (χ^2) test

Month	∑Chi-Squared values $\{(O_i-E_i)^2/E_i\}$									
	Normal	Log normal	Gumbel Min	Gumbel Max	Weibull (2)	Gamma	Beta	Log-Pearson (3)	Gamma (3)	Weibull (3)
Jan	Inf	84.07	Inf	Inf	11.76	572.61	Ext	28.34	8.59	472.98
Feb	Inf	89.32	Inf	Inf	65.20	3806.66	545.55	NA	247.29	Ext
Mar	Inf	212.29	Inf	Inf	201.19	Ext	Ext	NA	481.78	Ext
Apr	Inf	8.41	Inf	Inf	22.74	23.76	Ext	NA	73.11	Ext
May	Inf	307.29	Inf	Inf	510.95	Ext	Ext	NA	546.11	Ext
Jun	Inf	151.68	Inf	50.40	130.11	99.94	204.58	201.01	Ext	Ext
Jul	10.36	86.00	36.84	38.43	40.24	35.19	10.44	1.12	Ext	Ext
Aug	9.18	36.16	30.69	31.44	28.91	21.72	28.2	1237.83	Ext	Ext
Sep	Inf	291.64	Inf	301.53	211.23	195.34	272.57	189.29	Ext	Ext
Oct	Inf	802.19	Inf	Inf	336.71	549.81	Ext	NA	3957.40	Ext
Nov	Inf	1029.58	Inf	Inf	820.60	Ext	NA	NA	2155.60	Ext
Dec	Inf	560.37	Inf	Inf	472.82	NA	Ext	NA	1236.61	Ext
Total	Inf	3659	Inf	Inf	**2852.46**	Ext	Ext	NA	Ext	Ext

Inf: Infinity; Ext: Extremely high; NA: Distribution not fitted

Table 8: Probability analysis of Annual, Standard Non-monsoon and Monsoon weeks of rainfall series for the period 1971-2010 using Chi-squared test

Period	∑Chi-Square values $\{(O_i-E_i)^2/E_i\}$									
	Normal	Log normal	Gumbel Min	Gumbel Max	Weibull (2)	Gamma	Beta	Log-Pearson (3)	Gamma (3)	Weibull (3)
Yearly	13.95	6.87	40.68	9.31	21.18	8.09	18.32	7.34	7.81	8.96
SNMW	Inf	261.28	Inf	Inf	178.39	185.84	1294.73	NA	179.44	405.2
SMW	9.06	16.52	31.05	31.15	11.77	13.50	2.36	65.07	14.32	8.25

Inf: Infinity; NA: Distribution not fitted; SNMW: Standard non-monsoon week; SMW: Standard monsoon week

Annual rainfall of Tawa command indicates minimum of 651.81 mm during the year 2000 and maximum of 1897.67 mm in the year 2003. The standard deviation of annual series of rainfall is 302.04 mm. Annual coefficient of variation and coefficient of skewness in the region are 0.26 and 0.59 respectively.

Probability analysis of rainfall for the period 1971-2010

Probability analysis of rainfall series is done to know the assured rainfall in a region at different probability level, so that a risk free irrigation crop planning can be formulated. Probability analysis in the Tawa command is performed considering 40 years of daily rainfall data for the period 1971-2010. Data were converted into weekly, monthly and annual series before finding the best fit distribution in the region in a spread sheet programme.

In the study, a total of 9 distributions, both 2-parameters and 3-parameters, were fitted in the weekly, monthly and yearly series arranged earlier. All the distributions have been discussed in Table 1 with their Probability Density Function (PDF), Range and Parameters.

It is mandatory to test the goodness-of-fit of a probability distribution for identifying the best distribution which represent the region, to extrapolate a data series. Here, Chi-squared (χ^2) test was carried out to test the goodness of fit of the probability distributions considered in the study. The relationship of Chi-squared (χ^2) test statistic is given below:

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \qquad (2)$$

Where,

n = No. of observations; O_i = The observed values in the i^{th} observation; E_i = The expected (computed) values in the i^{th} observation.

Probability analysis of standard monsoon weeks, non-monsoon weeks, monthly and annual series of rainfall was made using nine probability distributions namely Normal, Log normal, Gumbel Min, Gumbel Max, Weibull (2), Gamma, Beta, Log Pearson (3), Gamma (3) and Weibull (3) distribution. Goodness-of-fit of these distributions was tested by Chi-squared (χ^2) test and values are presented in Table 7 and Table 8.As revealed from the Tables, the annual series of the rainfall data is best represented by Log normal distribution with minimum χ^2-value of 6.87, where as the standard monsoon and non-monsoon weeks are represented by Beta distribution and Weibull (2) distribution respectively. Probability analysis of monthly series reveals that Weibull (2) distribution is the best fit distribution representing the Tawa command. The monthly rainfall at different probability level by two parameter Weibull distribution is shown in Fig.5. Rainfall at 70% probability can be taken as assured in the crop planning in the Tawa command.

CONCLUSIONS

Proper crop planning in an irrigated area requires quality analysis of rainfall data as well as its correct interpretation. A poor, faulty analysis affects the sowing date, rainwater availability, irrigation need, and ultimately the net returns from the command. In the present study, 40 years daily rainfall data were analyzed for the Tawa irrigation project on weekly, monthly and annual basis, to arrive at analytical conclusion for better irrigation planning. The analysis of data in the region confirmed the variability in the mean rainfall received; hence the impact of climate change cannot be totally ignored. The command area is on high use since its inception from 1978. A lot of changes have occurred in the mean time in its cropping pattern and water utilization.The statistical analysis of rainfall data in the region confirms a instable monsoon system with mean annual rainfall of 1174.78 mm, mean monthly rainfall variation of 0.83 mm in the month of April to 404.27 mm in the month of July and mean weekly rainfall variation from 0.06 mm in the SW 16 to 97.94 mm in the SW 33.

The probability analysis of weekly, monthly and annual series of rainfall data was carried out by employing nine probability distributions namely Normal, Log normal, Gumbel Min, Gumbel Max, Weibull (2), Gamma, Beta, Log Pearson (3), Gamma (3) and Weibull (3) distribution. Goodness-of-fit of these distributions was tested by Chi-squared (χ^2) test. The annual series of the rainfall data is best represented by Log normal distribution with minimum χ^2-value of 6.87, where as the standard monsoon and non-monsoon weeks are represented by Beta distribution and Weibull (2) distribution respectively. Probability analysis of monthly series reveals that Weibull (2) distribution is the best fit distribution representing the Tawa command.

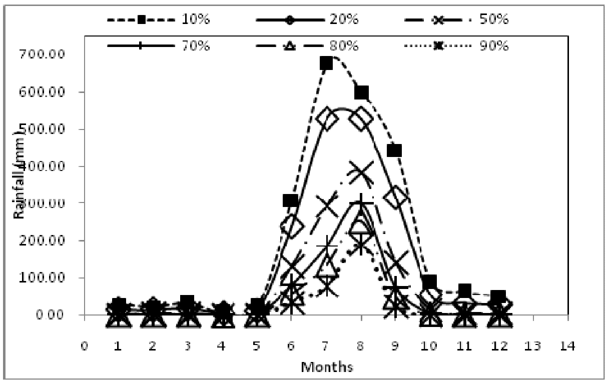


Fig.5. Monthly rainfall at different probability level by Log-normal distribution

ACKNOWLEDGEMENT

The authors, thankfully, acknowledges the Tawa Command Authority, Hoshangabad for providing rainfall station data due to which quality analyses of rainfall in the study have been made possible. Lastly, we acknowledge our thankfulness to State Data Centre, Bhopal, India for supporting during the study.

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