Journal of Agrometeorology 17 (2) : 234-240 (December 2015)

Weekly rainfall analysis for crop planning in rainfed Shivalik Himalayas of India

N.M. ALAM*,C JANA, PANKAJ PANWAR[1], GOPAL KUMAR[2], P.K. MISHRA, N.K. SHARMA and A.K. TIWARI[1]

ICAR-Indian Institute of Soil and Water Conservation, Dehradun

[1]ICAR-Indian Institute of Soil and Water Conservation, Research Center, Chandigarh

[2]ICAR-Indian Institute of Soil and Water Conservation, Research Center, Vasad

**Corresponding author: alam.nurnabi@gmail.com*

ABSTRACT

The study was carried out to compare various two-parameter probability distributions for identifying the most appropriate distribution to describe the weekly rainfall data of Standard Meteorological Week (SMW) from 22 to 42 weeks in Shivalik region of India. The ''best'' distribution among different data sets has been identiûed using Anderson–Darling (AD) test for goodness-of-ût. Single probability distribution, which can represent all the data sets, was not found among the distributions studied. Weibull distribution was best fit in about nine SMW, followed by Gamma distribution showing best fit in seven weeks out of the 21 weeks studied. Comparing total rainfall at different probability level with average rainfall, it was found that minimum assured rainfall with 50, 40 and 30 per cent probability is 21.35 % lesser, 0.04 % higher and 37.25 % higher, respectively than average rainfall. Thus minimum assured weekly rainfall at 40% probability level is a better representative of long-term average weekly rainfall data of the region. Appropriate time for maize sowing should be between 25th June to 1st July as minimum assured rainfall of more than 25 mm is available with 70 per cent probability. It was found that only short to medium duration maize varieties are suitable taking into account the rainfall pattern and duration in the region.

Keywords:Shivalik, distributions, Anderson–Darling (AD) test, Maximum likelihoodmethod, maize, Wald–Wolfowitz Run test

Shivalik Himalayas also sometimes described as lower/ outer Himalayas are sandwiched between Great Indian Himalayas and Indo-Gangetic Plains. Shivalik stretchesup to 3.33 million hectare area in north-western part of India (Yadav *et al.*, 2014). The region is undulating and has highrainfall variability along with other factors which hampers agricultural production and economic prosperity of the region. It is thus imperative to understand the underlyingprocessgeneratingrainfalldata, as moisture is most limiting factor in production. Such information is necessary forirrigationandcrop planning. This would also help in developing strategies for introduction of new crops, developing drought characterization index, designing of drainage structures and devising water harvesting policies.

Understanding rainfall variability and computation of minimum assured rainfall through probability distributions had been widely used. Cochran, 1954 used variance ratio test along with mixed gama probability distribution for describing skewed rainfall data. India Meteorological Department (IMD) (1995) computed minimum assured amount of rainfall at 40, 50, 60 and 70% probability levels for different stations employing two-parameter gamma probability distribution. The log-logistic probability distribution on the precipitation data was used by Shoukri*et al.* (1988). Gamma probability distribution was used by Stern and Coe (1984) and Hyndman and Grunwald (2000) for describing rainfall amount under generalized linear and additive model setup, respectively. Two-parameter probability distributions (normal, log-normal, Weibull, logistic, log-logistic, smallest and largest extreme value), and three-parameter probability distributions (log-normal, gamma, Weibull, and log-logistic) have been widely used for studying ûood frequency (Ashkar and Mahdi, 2003; Clarke, 2003), and drought analysis (Quiring and Papakryiakou, 2003; Alam *et al.,* 2014). Screening of most appropriate distribution from a menu of competing distributions remained a researchable issue for the last many decades. Location speciûc agricultural planning in general and crop planning in particular by analyzingperiodic rainfall data has been attempted by many researchers.

Table 1: Normality and independence test for rainfall 22 to 42 SMW

Week	Normality test		Independence test	
	A-D value	P value	U value	P value
22	2.729	<0.01	-0.689	0.491
23	2.351	<0.01	0.578	0.563
24	1.654	<0.01	0.010	0.999
25	2.923	<0.01	0.691	0.490
26	0.764	0.044	-0.614	0.539
27	2.897	<0.01	-0.426	0.670
28	1.882	<0.01	0.292	0.770
29	1.648	<0.01	-0.746	0.456
30	2.616	<0.01	-1.152	0.249
31	1.784	<0.01	1.143	0.253
32	2.304	<0.01	-1.605	0.109
33	0.820	0.032	1.314	0.121
34	1.536	<0.01	-0.438	0.662
35	1.608	<0.01	1.166	0.135
36	3.051	<0.01	-0.588	0.557
37	2.846	<0.01	-0.283	0.777
38	5.332	<0.01	0.507	0.612
39	2.730	<0.01	-0.655	0.512
40	2.683	<0.01	0.218	0.827
41	1.758	<0.01	0.029	0.977
42	1.017	<0.01	0.010	0.999

Gupta *et al.* (1975) suggested cropping systems for Doon Valley during rainy and winter crop seasons on the basis of expected amount of rainfall at 80% probability level. Similarly, Sharda and Das (2005) modelled weekly rainfall in sub-humid climate of Doon valley for crop planning. Stern and Coe (1982) analyzed daily rainfall data for crop planning in semi-arid tropics. Analysis of rainfall data has also been done for crop planning in coastal, semi-arid, dry farming and Himalayan foothill regions (Panigrahi, 1998; Tomar and Ranade, 2001).

Systematic study for selection of most appropriate distribution by comparing the probability distributions in the region is lackingfor describing non-Gaussian rainfall datain a Shivalik region. In this study, probability distributions have been compared and evaluated for their appropriateness to describe rainfall data using probability plot, Anderson–Darling (AD) test for goodness-of-ût and computing estimated percentiles. The developed probability distributions have been employed to obtain the minimum assured amount of rainfall at different probability levels in standard meteorological (SM) weeks. Furthermore, with minimum assured rainfall at 70% probability level planning for maize crop had been done for the region.

Table 2: Two and three parametric tests for rainfall during *kharif* season

SMWeek	Distribution	Location	Shape	ADvalue	Pvalue
22	Loglogistic	2.38	0.61	0.330	>0.250
23	Weibull	0.83	30.39	0.251	>0.250
24	Gamm	0.80	39.32	0.421	>0.250
25	Weibull	0.83	44.06	0.252	>0.250
26	Weibull	1.28	63.73	0.424	>0.250
27	Gamma	1.11	48.97	0.237	>0.250
28	Weibull	1.09	86.49	0.299	>0.250
29	Weibull	1.04	58.14	0.172	>0.250
30	Gamma	0.98	78.85	0.264	>0.250
31	Gamma	1.17	68.21	0.407	>0.250
32	Gamma	0.97	82.81	0.340	>0.250
33	Weibull	1.25	75.92	0.676	0.076
34	Gamma	1.08	50.77	0.221	>0.250
35	Gamma	0.94	56.70	0.429	>0.250
36	Weibull	0.92	64.78	0.440	>0.250
37	Weibull	0.87	42.75	0.329	>0.250
38	Loglogistic	2.53	0.81	0.281	>0.250
39	Lognormal	2.78	1.73	0.411	>0.250
40	Loglogistic	2.47	0.62	0.413	>0.250
41	Lognormal	2.10	1.56	0.197	>0.250
42	Weibull	0.88	16.37	0.234	>0.250

MATERIALS AND METHODS

Data

The daily rainfall (mm) data for53 years (1960–2012)was collected from Class A meteorological observatory located at Central Soil andWater Conservation Research and Training Institute, Research Centre, Chandigarh, India, which is situated at an elevation of 346 m with latitude and longitude of 30^{0} 43' N and 76^{0} 51'E, respectively. The observatory is located in Shivalik region representing sub-humid climate under the network of IMD, Pune, India. The daily rainfall data has beenconverted into SM weekly data employing standard procedure.

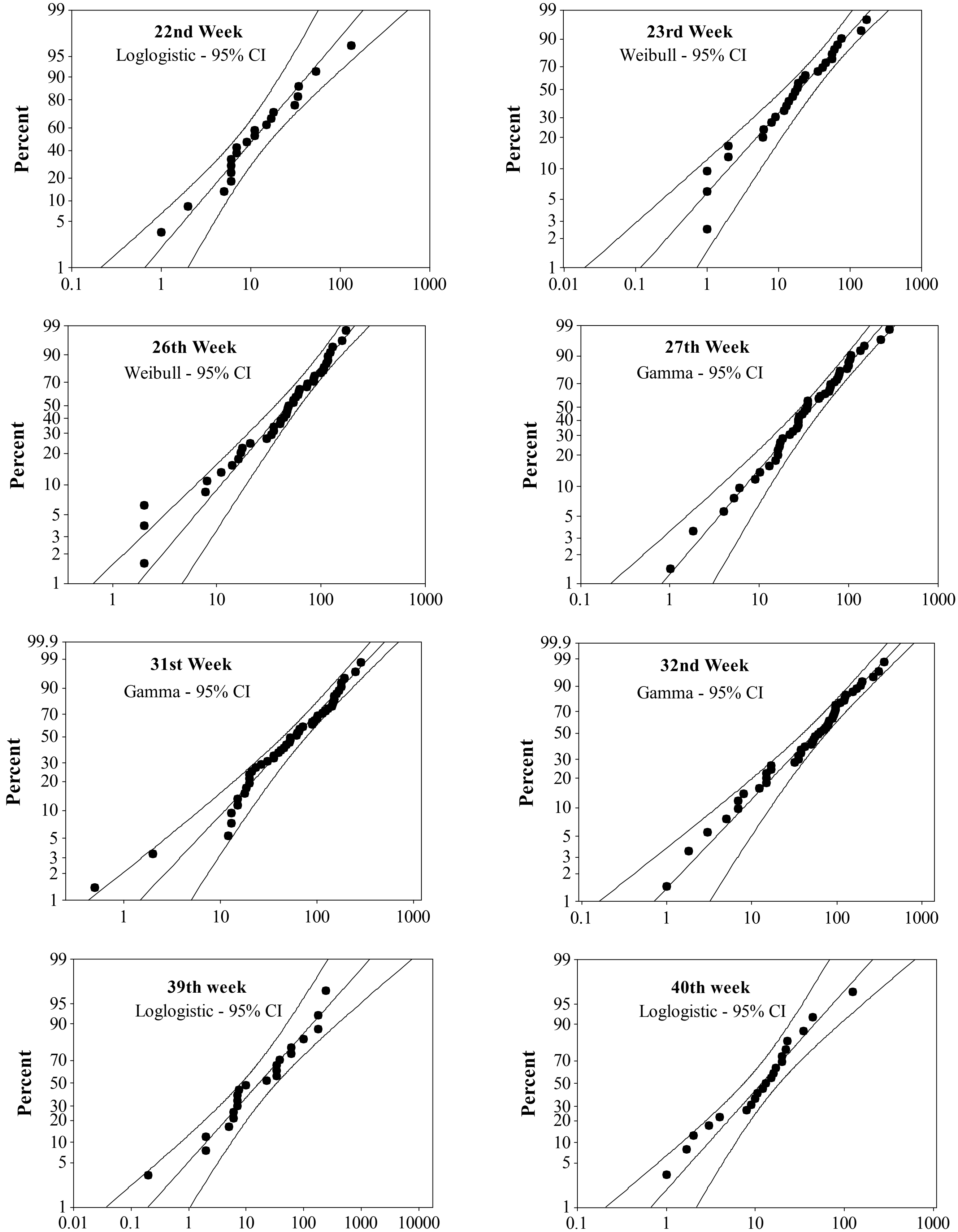

Fig 1: Best fit probability plots of two and three parametric tests distributions fitted to the data of different SMW

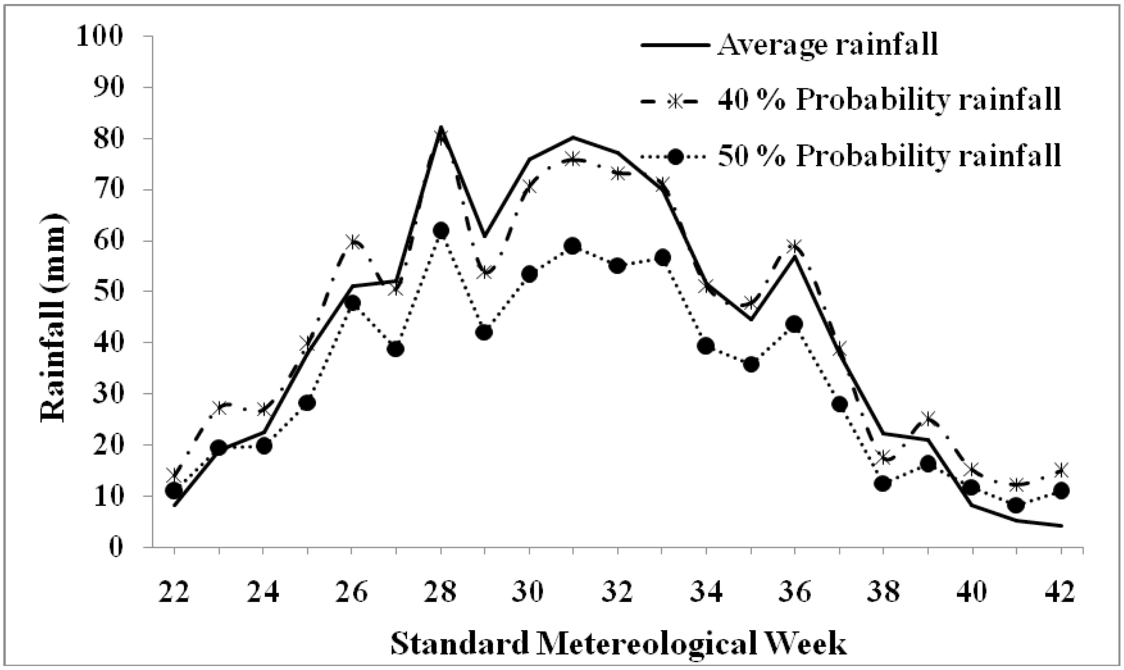

Fig 2: Comparison of minimum assured weekly rainfall at 40% and 50% probability level with the average weekly rainfall data

Statistical analysis

In this study, eight distributions, *viz*.: normal, log-normal,gamma,Weibull, logistic, log-logistic, smallest and largest extremevalue distributions are considered forselection of most appropriate distribution to describe the weekly rainfall data. These distributions are commonly used to describe the weekly rainfall data and arewell documented in literature (Rao and Hamed, 2000).The Anderson–Darling (AD) test (D'Agostino and Stephens 1986) has been employed in the present study for testing normality of data sets, which examines the null hypothesis that the data follow a normal probability distribution. The Anderson–Darling normality test has relatively better power and is especially effective in detecting departure from normality in the high and low values of a probability distribution.Various techniques are available for distribution parameter estimation. But as viewed by Sharda and Das (2005) maximum likelihood estimation is considered the most efûcient method since it provides the smallest sampling variance of the estimated parameters, compared to the other methods and involves the choice of parameter estimates that produce a maximum probability of occurrence of the observations. Maximum likelihood method has been used for estimation of parameters.

For testing the goodness of fit, Anderson–Darling goodness of fit test has been used which is better than other tests.The Anderson–Darling test statistic a*p*-value greater than or equal to thechosen a-level suggests that the probability distribution represents a good ût. If two ormore distributions ût the data set well, then the ûnal choice is made on the basis of smallestAD value and by comparing the probability plots ofdifferent distributions.

RESULTS AND DISCUSSIONS

Before ûtting different distributions to the data sets, non-normal behaviour of data sets and independence of observations were tested by Anderson–Darling test and Wald–Wolfowitz Run test, respectively. Results of Anderson–Darling normality test andWald–Wolfowitz test for independence pertaining to all the datasets are presented in Table 1.Anderson–Darling test revealed that all the data setswere non-normal at 1 % signiûcance level (SMW 32 at 5% significance level). While for run test, the calculated U values for all the SMW are non-significant. Thus, the null hypothesis ofindependence of all the data sets can be accepted at 5 % level of signiûcance, showing departure from the expected trend of persistence in the hydrological series. The eight distributions mentioned above were tested for Standard Meteorological Week (SMW) from 22 to 42. Maximum Likelihood (ML) estimates of parameters probability distributions were obtained by using non-zero total weekly rainfall values. The'best' distribution is selected using AD test, probability plot and by studying thesign of estimated percentiles. The best fitted model along with parameter estimates has been presented in Table 2.

Table 3: Minimum assured rainfall (mm) in different SMW at different probability levels

Week	Probability level									Avg. Rainfall
	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	(mm)
22	2.8	4.6	6.4	8.4	10.8	13.8	18.1	25.3	41.5	8.2
23	2.0	4.9	8.7	13.5	19.5	27.3	38.0	53.9	83.0	18.8
24	2.0	5.1	8.9	13.7	19.5	27.0	36.9	51.2	76.2	22.5
25	2.9	7.2	12.6	19.5	28.3	39.6	55.1	78.2	120.6	38.1
26	10.9	19.6	28.3	37.6	47.8	59.5	73.7	92.5	122.5	51.1
27	6.8	13.5	20.9	29.2	38.8	50.5	65.4	86.1	121.2	52.0
28	10.9	21.8	33.6	46.7	61.8	79.8	102.5	133.7	185.7	82.1
29	8.0	15.5	23.5	32.2	42.1	53.8	68.4	88.2	120.9	60.9
30	7.8	16.8	27.1	39.0	53.2	70.6	93.0	124.7	179.0	75.8
31	11.0	21.4	32.4	44.6	58.8	75.7	97.2	127.0	177.2	80.1
32	8.0	17.3	27.9	40.3	55.1	73.2	96.6	129.7	186.5	77.2
33	12.4	22.7	33.1	44.2	56.5	70.7	88.1	111.2	148.2	69.7
34	6.6	13.4	20.8	29.3	39.1	51.1	66.4	87.7	123.9	51.6
35	4.9	10.9	17.8	26.0	35.8	47.8	63.5	85.8	124.2	44.5
36	5.5	12.6	21.0	31.1	43.4	58.8	79.3	108.9	161.0	56.7
37	3.2	7.6	13.0	19.7	28.0	38.6	52.9	73.9	111.7	37.7
38	2.1	4.0	6.3	9.0	12.5	17.3	24.8	38.3	73.8	22.1
39	1.7	3.7	6.5	10.4	16.1	24.9	39.8	68.8	147.0	20.8
40	3.0	4.9	6.9	9.1	11.7	15.1	19.9	27.9	46.3	8.1
41	1.1	2.2	3.6	5.5	8.1	12.1	18.5	30.4	60.5	5.1
42	1.2	2.9	5.0	7.6	10.8	14.8	20.2	28.0	42.1	4.1
Total	**115.6**	**233.4**	**365.3**	**517.4**	**698.4**	**923.0**	**1219.0**	**1652.4**	**2454.0**	**888.1**

The Anderson–Darling goodness of fit testvalues for the best fit in each week along with ML estimates of parametersis presentedin Table 2. The corresponding probability plots with 95 per cent confidence interval for eight SMWs*viz*. 22, 23, 26, 27, 31, 32, 39 and 40 are presented in Fig. 1. Weibull distribution was best fit in about nine SMW, followed by Gamma distribution showing best fit in seven weeks out of the 21 weeks studied. Loglogistic distribution was best fit in four data set of SMW (22, 38, 39 and 40th week); Lognormal distribution was promising only in 41st SMW while other four distributions were not found suitable for the rainfall series.

Minimum assured amount of rainfall (mm) at different probability levels (0.1–0.9) was computed by using the 'best' distribution for each of the SM weeks and the results are presented in Table 3. Comparing total rainfall of different probability levels with average rainfall, it was found that minimum assured rainfall with 50, 40 and 30 per cent probability is 21.3 per cent lesser, 0.04 % higher and 37.2 % higher, respectively then average rainfall (Table 3). Taking 40 per cent probability of minimum assured rainfall of the area, it was found that it almost closely follow the trend of the average rainfall of the area, however, values of 50 per cent probability of minimum assured rainfall (Fig. 2) compared to the average rainfall of the area was quite less. It is thus concluded that minimum assured weekly rainfall at 40 per cent probability level is a better representative of long-term average weekly rainfall data of the region.

Application of rainfall analysis for crop planning

In Shivalik region maize-wheat is the traditional cropping sequence but yield of maize crop remains around10-15 qha^{-1}as it is grown as rainfed and many a time it is prone to prolonged moisture stress either during sowing or during the growing period (Yadav*et al.,* 2006). The need is to plan the cropping in such a way that it avoids critical stress period. During *Kharif*season it is desirable to complete the sowing operation 12-15 days before the onset of monsoon. However, in rainfed areas, the sowing time should coincide with onset of monsoon. Therefore, in Shivalik appropriate time for rainfedmaize sowing isbetween 25th June to 1st July as minimum assured rainfall of more than 25 mm is available with 70 per cent probability. This will ensure effective utilization of available rainwater for enhanced maize production. There are four stages after sowing*viz.*knee high stage also referred to as eight leaf stage (V8), flowering/ tasseling (VT) and grain filling (GF) which are most sensitive stages for water stress and hence soil moisture should be ensured at these stages. To ensure moisture during these stages early (takes 80 – 85 days to mature) to medium (takes 85-95 days to mature) maturing varieties should be selected (Handbook of Agriculture, 2006). Inmedium duration maize variety of 93 days (germination: 11 days, growth: 35 days, tasseling: 11 days, silking: 7 days, milking: 14 days and ripening: 15 days) (Sharda and Das, 2005) the V8 stage will come at SM week 30 when minimum assured rainfall of 27.1 mm will be available, the tasseling stage will come at SM week 32 when 27.9 mm assured rainfall will be available and grain filling/ milking stage will come in SM week 35 and 36 when 17.8 mm and 21.0 mm minimum assured rainfall is expected with 70 per cent probability. After milking stage/ grain filling stage dry season for ripening is required which will be available after SM week 37 when only 13.0 mm of rainfall and subsequently lesser rainfall will be available which will also ensure easy harvesting and drying of crops.

CONCLUSION

A single probability distribution was not adequate to represent the entire data set. Minimum assured weekly rainfall at 40per cent probability level was found to be a better representative of long-term average rainfall data. Taking 70 per cent probability of minimum assured rainfall, short and medium duration maize varieties are suitable for the region as these varieties can be sown in last week of June (SMW 26) and can be harvested in 2nd week of September (SMW 37 and 38) thus avoiding dry phases during sowing and milking/grainfill stage thus giving higher production.

ACKNOWLEDGEMENT

The authors are thankful for the pain staking efforts of Technical Officers involved in collection and compilation of meteorological data.

REFERENCES

Alam, N.M., Raizada, A., Jana, C., Meshram, R.K. and Sharma, N.K. (2014).StatisticalModeling of Extreme Drought Occurrence in Bellary District of Eastern Karnataka.*Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci*., doi:10.1007/ s40011-014-0381-0.

Ashkar, F. and Mahdi, S.(2003).Comparison of two ûtting methods for the log-logistic distribution.*Water Resour. Res*., 39 (8): 1217, doi:10.1029/2002WR001685.

Clarke, R.T. (2003).Comparison of estimators of linear time trend inWeibull-distributed low ûows.*Water Resour. Res*., 39 (7): 1180, doi:10.1029/2002WR001640.

Cochran, W.G. (1954).Some methods for strengthening the common chi-square tests.*Biometrics*, 10 (4): 417–451.

D'Agostino, R.B. and Stephens, M.A. (Eds.) (1986).Goodness-of-ût Techniques. Marcel Dekker.

Gupta, S.K., Babu, Ram and Tejwani, K.G. (1975).Weekly rainfall of India for planning cropping programme.*Soil Conserv.Digest.,* 3 (1), 31–36.

Handbook of Agriculture (2006). Indian Council of Agricultural Research: 1346p.

Hyndman, R.J. andGrunwald, G.K. (2000).Generalized additive modelling of mixed distribution Markov models with application to Melbourne's rainfall.*Aust. N. Z. J. Stat.,* 42 (2): 145–158.

India Meteorological Department (1995).Weekly Rainfall Probability for Selected Stations of India, vol. II.Division of Agricultural Meteorology, India Meteorological Department, Government of India.

Panigrahi, B. (1998).Probability analysis of short duration rainfall for crop planning in coastalOrissa.*Ind. J. Soil Conserv.,* 26 (2): 178–182.

Quiring, S.M. andPapakryiakou, T.N. (2003).An evaluation of agricultural drought indices for the Canadian Prairies. *Agric. Forest Meteorol.*, 118: 49–62.

Rao, A. R. andHamed, K.H. (2000). Flood Frequency Analysis. CRC Press.

Sharda, V.N. and Das, P.K. (2005).Modelling weekly rainfall data for crop planningin a sub-humid climate of India.*Agr. Water Manage.,* 76: 120–138.

Shoukri, M.M., Mian, I.U.H. and Tracy, D.S.(1988).Sampling properties of estimators of the log-logistic distribution with application to Canadian precipitation data. *Can. J. Stat.*, 16 (3): 223–236.

Stern, R.D. and Coe, R. (1982).The use of rainfall models in agricultural planning. *Agric. Meteorol*., 26: 35–50

Stern, R.D. and Coe, R.(1984).A model ûtting analysis of daily rainfall data. *J. R. Stat. Soc. A.*, 147 (1): 1–34.

Tomar, A.S. andRanade, D.H. (2001).Predicting rainfall probability for irrigation scheduling in black clay soil in Indore Region of Madhya Pradesh. *Ind. J. Soil Conserv*., 29 (1): 82–83.

Yadav, R.P, Singh, P., Aggarwal, R.K. and YadavM.K. (2006).Improved technology for sustainable production of maize (*Zea mays*) in Shivalik foothills of Himachal Pradesh. *Ind. J. Dryland Agric. Res. Dev*., 21(1): 1-6.

Yadav, R.P., Panwar P., Arya, S.L. and Mishra P.K. (2014).Revisit of Shivalik Region in different states of North-western India. *J.Geologi. Soc. India* (Accepted)

Received : October 2014 ; Accepted : June 2015