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Evaluation of Probability Distribution Technique for Predication of Weekly Maximum Rainfall and Crop Planning for North Bihar

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A B S T R A C T

Probability distribution technique used to predict the weekly maximum rainfall. In India 60% of total net sown area comes under rainfed. More than 65% population depends on agriculture, but, it contributes only 15.7% GDP of India. The rainfall distribution in country is non uniform which varies from place to place as well as time to time, therefore, study of probability distribution technique needed for understand rainfall characteristic and distribution. Appropriate analysis of rainfall data of 32 years from 1980 to 2011 was done for North Bihar. It was found that maximum rainfall 223 mm at 10% probability level minimum 2.57 mm at 90% probability level during 26th week and. Gumbel Distribution technique has found to be best suitable for evaluating weekly maximum rainfall up to 80% probability level by Chi Square Test. Crop planning at 80% probability level was considered, since an appreciable amount of rainfall is available from 25 to 38 week and maximum rainfall. In pusa region for Kharif season rice crop varieties such as Prabhat, Bhagavati for up land and Saroj, Rajendra Kasutri, Rajendra Subhashni, for low land are may be suitable. For Rabi season wheat, Maize, Mustard, Rai, Tori, crop suitable for upland and lowland.

Introduction

Rainfall is one of the most important natural resource input to crop production in the tropical and subtropical region. Importance of probability distribution technique to predict rainfall can be understand by the fact that in India 60% of total net sown area comes under rainfed land. Despite this progress, marginal and small farmers constituting 80% of agricultural income group, still depend on rainfed farming. But it contributes only 15.7% GDP of India (2010) www.worldagriculture.com, www.wikipedia.com). One of the most important problems in hydrology deals with interpreting a post record of hydrology event in future probability of occurrences. This problem arises in the estimation of frequencies of flood, drought, rainfall etc. Probability and frequency analysis of rainfall data enables us to determine the expected rainfall at various chances.

Bhakar *et al.*, (2006) calculated frequency analysis of consecutive days maximum rainfall. They tested by comparing the Chi-

squre value and found that Gama Distribution was best fit for Banswara, Rajsthan region. Panda *et al.,* (2009) analysed distribution functions for rainfall data (1969-2007) of Koraput district of Orissa for judicious crop planning. They found that there is only 4.3 mm rainfall available during rabi season at 70% probability level. They deduced that a suitable combination of crops like wheat+tomato, wheat+potato, tomato+bean and potato+cabbage can be successfully grown by the farmers during rabi season from the harvested water. Singh *et al.,* (2009) analysed variation of seasonal rainfall and probabilities of occurrence of assured weekly rainfall provide useful information for efficient agricultural management. They studied seven stations of Himachal Pradesh have been selected for the analysis of the rainfall data. They applied probability distribution revealed that high rainfall belt is located in the north western part of the state. For better apple production, monsoon rainfall plays significant role. Chand *et al.,* (2011) analysed of rainfall data for 34 year (1975-2008) Jhansi distric of Bundelkhand agro-climatic zone of U.P. They analysed to weekly monthly seasonal and annual probability at different levels of rainfall for suitable crop planning. They found 70% of initial probability of a dry week from 1 to 24th week and wet week 26 to 37th week. Jhakhar *et al.,* (2011) analysed the probability distribution of rainfall characteristic of Semiliguda in Koraput Orissa they applied Weibull's method and approximately closely the linear relationship between the rainfall and plotting position they found occurrence of 75% probable rainfall in Kharif summer and Rabi season are 1095.5 mm 91.4mm and 83 mm respectively then selection of seed bad preparation, crop verities and choice of crop pattern. The specific objectives of study are prediction the observed weekly rainfall at different probability levels using Weibull's method, evaluation probability distribution technique to predict weekly maximum rainfall and development of crop planning based on predicated weekly rainfall for Pusa Samastipur, Bihar.

Materials and Methods

The study area is selected at Pusa, Samastipur, Bihar, India at a Reference Level of 52 m above the M.S.L at 25.98^0N latitude and 85.67^0E longitude and the climate is a humid subtropical. Altitude of the site is 52.92 m above mean sea level. Experimental site is under humid sub-tropical climate, greatly influenced by the south-west monsoon. The main characteristic of the climate is hot-dry summer followed by cold winters. Average annual rainfall is 1270 mm, out of which about 1026 mm is received during the monsoon season from June to October. Soil type is sandy clay loam with average available moisture content 12.01%. The daily rainfall data of 32 years (1980-2011) were collected from metrological observatory location in Pusa for study purposes.

Evaluation of probability distribution technique for prediction of weekly maximum rainfall

Weibull's distribution

The weekly rainfall data were analysed for computation of weekly probable rainfall amount at 10, 20, 30, 40, 50, 60, 70, 80 and 90 percentage probability levels by using Weibull equation.

$$= \frac{M}{(N+1)}$$

P ... 1

Where, P = Probability (friction), T = Return period, M = rank of the observed rainfall, N = total number of year recorded

Gumble distribution

Gumbel distribution defined a weekly maximum Rainfall of 52 week and annual series of maximum Rainfall. According to this theory of extreme event the probability of occurrence of an event equal to or larger than value X is

$$P(X \geq X_0) = 1 - e^{-e^{-y}} \quad \ldots 2$$

In which y is a dimension variable given by

$$y = a(X - \bar{X}) \quad \bar{X}$$

, a = - 0.450056 σ_x...3

$$Y = \frac{1.285(X-\bar{X})}{\sigma x} + 0.577 \ldots 4$$

$\bar{X}$

Where, = mean of variant σx = standard deviation of variant X

In paretic it is the value of x for a given P that is required and as such eqn. is tramped as

$$Y_P = \ln[\ln(1-P)] \quad \ldots 5$$

Noting that the return period T = $\frac{1}{P}$ and designating

$$Y_T = -\left[ln.\, ln\frac{T}{T-1}\right] \quad \ldots 6$$

The value of variate X with a return period T is

$$X_T = \bar{X} + K\sigma_{n-1}) \quad \ldots 7$$

Where, σ_{n-1}= Standard deviation of the sample of size N = $\sqrt{\frac{\sum(X-\bar{X})^2}{N-1}}$ ...8

K = Frequency factor expressed as

$$K = \frac{Y_{l-\bar{Y}_n}}{S_n} \quad \ldots 9$$

$\bar{Y}_n$ = reduced mean, a function of sample size N

$\bar{Y}_n$

N→∞, → 0.557

S_n = reduced standard deviation a function of sample size N for N →∞, S_n → 1.2825

Log Pearson type –III distribution

The Log Pearson Type III Distribution is statically technique for predication of extreme rainfall value at different probability level.

In this the variety first transformed into logarithmic form (base 10) and transformed data is then analysed if x is the variant of a random hydrologic series then the series of Z varieties.

Where,

Z = Log x... 10

Are first obtained for this Z series for any recurrence interval

$$Z_T = \bar{Z} + K_Z\sigma_z \ldots 11$$

Where, K_z = Coefficient a frequency factor which is function of recurrence interval T and the coefficient of skew C_s

σ_z = Standard deviation of the Z variant Sample

$$\sigma_z = \sqrt{\frac{\sum(Z-\bar{Z})^2}{(N-1)}} \quad \ldots 12$$

C_s = Coefficient of skew of variant Z

$$= \frac{N\sum(Z-\bar{Z})^2}{(N-1)(N-2)(\sigma_z)^2} \quad \ldots 13$$

$\bar{Z}$ = Mean of the Z values, N = Sample size = Number of week of record

The variation of Kz = f (Cs, T); X_T = antilog (Z_T)

Chi-square test of goodness of fit

The chi-square test is used to determine whether there is a significant difference between the expected frequencies and the observed frequencies in one or more categories.

It is known as " chi-square goodness of fit" it enable us to find if the deviation to the experiment from theory is just by chance or is it really due to the inadequacy of the theory to fit the observed data.

If O_i (i=1, 2….n) is a set of observed frequency and E_i (i=1, 2…..n) is corresponding set of expected frequency then Karl Pearson's Chi-square given by

$$\chi^2 = \sum_1^n \frac{(O_i - E_i)^2}{E_i} \quad \ldots 14$$

The distribution having the least sum of the Chi square (χ^2) value for all probability level is judged best.

Results and Discussion

Observed rainfall amount

The weekly rainfall values were calculated using Weibull method at various recurrence intervals i.e.10, 5, 3.33, 2.5, 2, 1.6, 1.42, 1.25, 1.11, 1.01 years, are present in table 2. The table value indicates that there is a large variation in observed value among all different probability levels 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%. At 80% probability level the range of maximum and minimum observed weekly rainfall was obtained as 17.28 mm and 0 mm respectively, similarly the value of maximum rainfall equal to 223, 181,132, 83.36, 68.3, 45.76, 28.73, 17.28 and10 mm were obtained at 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90% probability level respectively.

Expected weekly rainfall amount

The expected maximum weekly rainfall values were computed using Log-Person Type–III distribution,

Normal distribution and Gumbel distribution for different probability levels. The obtained results and present in table 1.

The expected weekly maximum rainfall at different probability level found with help of Gumble distribution shown in table 1.

Sander deviation (σ) = 125.32, Mean ($\overline{X}$) = 118.4

Log Pearson Type III distribution used for predicts weekly maximum rainfall. The obtained expected rainfall value at different probability level represented in table 1. Average $(\log x) = Z = 1.789$, Standard deviation of Z=0.545, Skewness coefficient (C_s) =-0.1502 It was expected that weekly max rainfall for different probability level

10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90% are 293.87, 174.30, 123.50, 87.52, 62.02, 42.87, 30.24, 21.11 and 11.80 mm respectively.

Log Normal Distribution is statically method also used for prediction weekly maximum rain fall at different probability level. The obtained results are shown in table 1.

Average (log x) = Z = 1.789, Standard deviation of Z = 0.545, Skewness coefficient (C_s) =0

The weekly maximum expected rainfall at different probability level 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, are 300.59, 172.99, 121.61, 85.48,60.10, 42.25, 29.71, 20.88, 12.01, respectively.

Table.1 Computed values of observed and theoretical weekly maximum rainfall and there goodness of fit by Chi -squire value for maximum rainfall

Probability (%)	Return period (years)	Observed max weekly rainfall (x) (mm)	Expected weekly maximum rainfall			Chi-square		
			Gumbel Distribution (mm)	Log Pearson Type III Distribution (mm)	Log Normal Distribution (mm)	Gumbel Distribution	Log Pearson Type III Distribution	Log Normal Distribution
10	10	307.78	301.57	293.87	300.59	0.127	0.658	0.172
20	5	248.06	220.66	174.30	172.99	3.40	31.21	32.57
30	3.33	168.47	170.27	123.50	121.61	0.019	16.37	18.05
40	2.5	104.92	132.15	87.52	85.49	5.61	3.46	4.42
50	2	47.5	98.77	62.02	60.10	26.61	3.399	2.64
60	1.66	40.52	68.72	42.87	42.25	11.57	0.13	0.07
70	1.42	26.05	39.17	30.24	29.71	4.399	0.58	0.45
80	1.25	19.66	8.10	21.11	20.88	16.49	0.10	0.07
90	1.11	11.79	-30.98	11.81	12.02	-59.05	1.83	0.0043
					Total ($\chi^{2)}$S value	9.18	55.91	58.45

Table.2 Weekly rainfall at different probability level

Weeks	Probability									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
1	4	1.94	0	0	0	0	0	0	0	0
2	10.27	0	0	0	0	0	0	0	0	0
3	10.78	0	0	0	0	0	0	0	0	0
4	13.1	4.22	0	0	0	0	0	0	0	0
5	10.67	3.08	0	0	0	0	0	0	0	0
6	6.4	2.52	0.14	0	0	0	0	0	0	0
7	17.45	6.26	0.48	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	8.27	3.72	0.17	0	0	0	0	0	0	0
10	4.09	0.16	0	0	0	0	0	0	0	0
11	2.68	0.12	0	0	0	0	0	0	0	0
12	9.25	1	0	0	0	0	0	0	0	0
13	4.82	0.92	0	0	0	0	0	0	0	0
14	12.9	1.92	0	0	0	0	0	0	0	0
15	7.16	0.04	0	0	0	0	0	0	0	0
16	21.84	12.6	6.15	0	0	0	0	0	0	0
17	18.91	11.92	7.96	4.72	0	0	0	0	0	0
18	26.6	20.18	14.29	6.32	0.5	0	0	0	0	0
19	48.73	32.34	15.67	10.3	3.3	0.62	0	0	0	0
20	41.22	25.44	17	5.6	2.35	0.08	0	0	0	0
21	91.55	54.46	38.03	21.72	13.35	3.84	0	0	0	0
22	49.72	39.02	26.95	17.74	13.75	10.06	0.18	0	0	0
23	99.28	72.5	42	21.66	13.3	6.48	2.94	0	0	0
24	96.6	56.96	38.74	22.24	11.5	8.6	4.86	0	0	0
25	120.26	78.98	71.16	55.28	39.5	23.76	18.98	6.98	0	0
26	223.83	135.8	92	65.24	37.25	27.26	18.75	9.22	3	0
27	211.08	181.6	132.45	76.56	59.95	40.68	20.36	11.56	3.15	1.13
28	211.28	142.26	94.22	83.36	68.3	45.76	24	12.92	4.29	0
29	207.11	129.02	93.29	74.16	48.4	37.82	28.73	16.78	3.09	0
30	127.47	102.62	87.1	67.92	53.95	36.66	20.9	11.4	4.25	0.21
31	149.75	105.08	75.16	47.9	41.6	26.8	23.56	17.02	10	2.58
32	173.73	93.52	70.67	60.02	39.5	28	23.03	8.2	0.42	0
33	216.75	139.4	110.92	84.5	54.05	38.34	25.04	9.92	0.81	0
34	163.77	140.24	77.21	49.4	40.6	32.62	21.88	17.28	4.75	0
35	134.84	103.48	67.18	47.8	35.55	29.96	24.6	8.28	1.8	0
36	200.38	126.22	88.32	57.26	37.4	29.88	19.11	10.4	0.99	0
37	113.04	77.92	59.18	34.14	29	20.04	15.44	10	8.7	1.55
38	90.74	70.8	55.8	40.28	32.3	16.76	6.72	2.2	0	0
39	143.56	62.78	33.2	21.82	14.3	6.16	8.16	0	0	0
40	80.78	33.56	18.5	5.2	1.3	0	0	0	0	0
41	47.46	18.52	13.2	4.68	2	0	0	0	0	0
42	62.06	19.36	5.28	0.24	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0
44	8.96	0	0	0	0	0	0	0	0	0
45	10.3	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0
47	0.24	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0
52	15.2	6.96	0	0	0	0	0	0	0	0

Evaluation of probability distribution technique

The calculated observed and expected weekly maximum rainfall value and there goodness of fit value by Chie-square (χ^2) test for evaluating most suitable probability distribution. The three probability distribution techniques use for evaluation. The Gumble Distribution was found to most suitable for 7 days maximum rainfall because of showing lowest Chie square value as shown in table 1.

Crop planning for up land

Considering the rainfall at 80% probability level for crop planning in upland area. It was observed that appreciable amount of rainfall is available from 25th to 38th week. Maximum amount of rainfall which is (17.28 mm) expected to be available in 34th week of the year which is based on 32 year data 1980-2011.Crop like Maize, Arhar, Groundnut, fodder crop etc. i.e. after one week of the perception of rain 25th week. As 80% probability level there is less expected rainfall between 39th to 52nd week but that period is critical for late maturing variety of paddy there may be reduction in yield absence of irrigation, this absence of rainfall may facility the harvesting of early variety.

Different varieties rice crop such as Prabhat, Bhagvati, sown predominately. Pusa region soil and rainfall distribution is suitable for Tobacco cultivation at commercial level.

Crop planning for low land area

Crop planning for low land area at 80% probability level will be different than the upland because crop are lost by water logging or submergence in these area. The crop planning for this area can be done at 80% probability level early sowing of paddy (deep water paddy) can be done in 22nd week of the year. Thus standing plant may be such that they can resist water logging. This is expected to be started from 25th week at 80%probability level.

Long duration variety rice crop like Saroj, Rajendra Kasturi and Rajendra Subhasni may be suitable for low land area.

Based on the analysis of 32 years rainfall data of pusa, it was found that the maximum weekly observed rainfall by using Weibull method at 80% probability level was 17.28 mm, similarly the value of maximum rainfall equal to 223, 181,132, 83.36, 68.3, 45.76, 28.73, 17.28 and10 mm were obtained at 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90% probability level respectively. The expected maximum weekly rainfall values were computed using Log-Person Type–III distribution, Log-Person Normal distribution and Gumbel distribution for different probability levels it was found as 293.87 mm, 300.59 mm and 301.57 mm respectively at 10% probability level among three probability distribution techniques for evaluation. The Gumble Distribution was found to most suitable for 7 days maximum rainfall at pusa. Considering the rainfall at 80% probability level for crop planning in upland area. It was observed that appreciable amount of rainfall is available from 25th to 38th week. Crop planning for low land area at 80% probability level will be different than the upland because crop are lost by water logging or submergence in these area. The crop planning for this area can be done at 80% probability level early sowing of paddy (deep water paddy) can be done in 22nd week of the year. Thus standing plant may be such that they can resist water logging. This is expected to be started from 25th week at 80%probability level. In pusa region for Kharif season rice crop varieties such as Prabhat, Bhagavati for up land and Saroj, Rajendra Kasutri, Rajendra Subhashni, for low land are may be suitable. For Rabi

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