



Rainfall probability analysis for crop planning in Deogarh district of Odisha, India

C.R.Subudhi* , Sukanya Suryavanshi, Nibedita Jena and R.Subudhi

Department of Soil and Water Cons. and Eng, CAET, OUAT, Bhubaneswar-751003, Odisha

*Email: rsubudhi5906@gmail.com, +919437645234

Abstract

This study was under taken in the U.G. thesis work in the Dept. Of SWCE, CAET, OUAT, Bhubaneswar during the year 2018-19. Deogarh district has geographical area of 2781.66 sq.km. and latitude of 21°35'N and a longitude of 84°30' E. The average rainfall at Deogarh district is around 1514.8 mm, though it receives high amount rainfall but most of the rainfall occurred during *kharif*. So most of the crops get low yield due to improper crop planning. Thus, this study is proposed to be undertaken with the following objective: Probability analysis of annual, seasonal and monthly rainfall data of Deogarh district. So rainfall data were collected from OUAT, Agril Meteorology Dept. from 2001 to 2017(17 years) monthly, seasonal and annual rainfall were analyzed .Probability analysis have been made and equations were fitted to different distributions and best fitted equations were tested. Monthly, Annual and seasonal probability analysis of rainfall data shows the probability rainfall distribution of Deogarh district in different months, years and seasons. It is observed that rainfall during June to Sep is slightly less than 1000 mm and cropping pattern like paddy(110 days) may be followed by mustard is suitable to this region. Also if the *kharif* rain can be harvested and it can be reused for another *rabi* crop by using sprinkler or drip irrigation, which will give benefit to the farmers. Annual rainfall of Deogarh district is 1514.8 mm at 50% probability level.

Key words: Crop planning, probability analysis, rainfall

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Introduction

Deogarh district has geographical area of 2781.66 sq.km. and latitude of 21°35'N and a longitude of 84°30' E. The average rainfall at Deogarh district is 1514.8 mm, most of the rainfall occurred during *kharif*. Thus, this study is proposed to be undertaken with the following objective: Probability analysis of annual, seasonal and monthly rainfall data of Deogarh district. Thom (1966) employed mixed gamma probability distribution for describing skewed rainfall data and employed approximate solution to non-linear equations obtained by differentiating log likelihood function with respect to the parameters of the distribution. Subsequently, this methodology along with variance ratio test as a goodness-of-fit has been widely employed Kar *et al.*, (2004), Jat *et al.*, (2006), Senapati *et al.*,

(2009) applied incomplete gamma probability distribution for rainfall analysis. In addition to gamma probability distribution, other two-parameter probability distributions (normal, log-normal, Weibull, smallest and largest extreme value), and three-parameter probability distributions (log-normal, gamma, log-logistic and Weibull) have been widely used for studying flood frequency, drought analysis and rainfall probability analysis (Senapati *et al.*, 2009). Gumbel (1954) and Chow (1964) have applied gamma distribution with two and three parameter, Pearson type-III, extreme value, binomial and Poisson distribution to hydrological data (Weibull, 1951).

Materials and methods

The data were collected from District Collector’s Office, Deogarh district for this study. Rainfall data for 17 years from 2001 to 2017 are collected for the presented study to make rainfall forecasting through different methods.

Probability Distribution Functions

For seasonal rainfall analysis of Deogarh district, three seasons- *kharif* (June-September), *rabi* (October to January) and summer (February to May) are considered.

The data is fed into the Excel spreadsheet, where it is arranged in a chronological order and the Weibull plotting position formula is then applied. The Weibull plotting position formula is given by

$$p = \frac{m}{N + 1}$$

where *m* = rank number

N = number of years

The recurrence interval is given by

$$T = \frac{1}{p} = \frac{N + 1}{m}$$

The values are then subjected to various probability distribution functions namely-normal, log-normal (2-parameter), log-normal (3-parameter), gamma, generalized extreme value, Weibull, generalized Pareto distribution, Pearson, log-Pearson type-III and Gumbel distribution. Some of the probability distribution functions are described as follows:

Normal Distribution

The probability density is

$$p(x) = (1/\sigma\sqrt{2\pi}) e^{-(x-\mu)^2/2\sigma^2}$$

where *x* is the variate, μ is the mean value of variate and σ is the standard deviation. In this distribution, the mean, mode and median are the same. The cumulative probability of a value being equal to or less than *x* is

$$p(x \leq) = 1/\sigma\sqrt{2\pi} \int_{-\infty}^x e^{-(x-\mu)^2/2\sigma^2} dx$$

This represents the area under the curve between the variates of $-\infty$ and *x*.

Log-normal (2-parameter) Distribution

The probability density is

$$p(x) = (1/\sigma_y \sqrt{2\pi}) e^{-(y-\mu_y)^2/2\sigma_y^2}$$

where $y = \ln x$, where *x* is the variate, μ_y is the mean of *y* and σ_y is the standard deviation of *y*.

Log-normal (3-parameter) distribution

A random variable *X* is said to have three-parameter log-normal probability distribution if its probability density function (pdf) is given by:

$$f(x) = \begin{cases} \frac{1}{(x - \lambda)\sigma\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\left(\frac{\log(x - \lambda) - \mu}{\sigma}\right)^2\right\}, & \lambda < x < \infty, \mu > 0, \sigma > 0 \\ 0, & \text{otherwise} \end{cases}$$

where μ, σ and λ are known as location, scale and threshold parameters, respectively.

Pearson Distribution:-

The general and basic equation to define the probability density of a Pearson distribution

$$p(x) = e \int_{-\infty}^x \frac{a + x}{b_0 + b_1x + b_2x^2} dx$$

where *a, b*₀, *b*₁ and *b*₂ are constants.

The criteria for determining types of distribution are β_1, β_2 and *k* where

$$\beta_1 = \frac{\mu_3^2}{\mu_2^3}$$

$$\beta_2 = \frac{\mu_4}{\mu_2^2}$$

$$k = \frac{\beta_1(\beta_2 + 3)^2}{4(4\beta_2 - 3\beta_1)(2\beta_2 - 3\beta_1 - 6)}$$

Where μ_2, μ_3 and μ_4 are second, third and fourth moments about the mean.

Log-Pearson Type III Distribution

In this the variate is first transformed into logarithmic form (base 10) and the transformed data is then analyzed. If *X* is the variate of a random hydrologic series, then the series of *Z* variates where

$$z = \log x$$

are first obtained. For this *z* series, for any recurrence interval *T* and the coefficient of skew *C*_s,

σ_z = Standard deviation of the *Z* variate sample

$$= \sqrt{\sum (z - \bar{z})^2 / (N - 1)}$$

And *C*_s = coefficient of skew of variate *Z*

$$= \frac{N \sum (z - \bar{z})^3}{(N-1)(N-2)\sigma_z^3}$$

\bar{z} = mean of *z* values

N = sample size = number of years of record

Generalized Pareto Distribution

The family of generalized Pareto distributions (GPD) has three parameters μ, σ and ξ .

The cumulative distribution function is

$$F_{(\xi, \mu, \sigma)}(x) = \begin{cases} 1 - \left(1 + \frac{\xi(x - \mu)}{\sigma}\right)^{-\frac{1}{\xi}} & \text{for } \xi \neq 0 \\ 1 - \exp\left(-\frac{x - \mu}{\sigma}\right) & \text{for } \xi = 0 \end{cases}$$

For $x \geq \mu$ when $\xi \geq 0$ and $x \leq \mu - \frac{\sigma}{\xi}$ when $\xi < 0$, where $\mu \in \mathbb{R}$ is the location parameter, $\sigma > 0$ the scale parameter and $\xi \in \mathbb{R}$ the shape parameter.

The probability density function is

$$f_{(\xi, \mu, \sigma)}(x) = \frac{1}{\sigma} \left(1 + \frac{\xi(x - \mu)}{\sigma}\right)^{-\left(\frac{1}{\xi} + 1\right)}$$

Or

$$f_{(\xi, \mu, \sigma)}(x) = \frac{\sigma^{-\frac{1}{\xi}}}{\left(\sigma + \xi(x - \mu)\right)^{\left(\frac{1}{\xi} + 1\right)}}$$

again, for $x \geq \mu$, and $x \leq \mu - \frac{\sigma}{\xi}$ when $\xi < 0$

Result and discussion

The various parameters like mean, standard deviation, RMSE value were obtained and noted for different distributions. The rainfall at 90%, 75%, 50%, 25% and 10% probability levels are determined. The distribution “best” fitted to the data is noted down in a tabulated form in Table 1.

In the present study, the parameters of distribution for the different distributions have been estimated by FLOOD frequency analysis software. The rainfall data is the input to the software programme. The best fitted distribution of different month and seasons and annual were presented in Table 1. The annual rainfall in 50% probability was found to be 1514.8 mm for Deogarh block of Odisha. During *Kharif* at 50% probability level, the

rainfall is 1266.8 mm where as only 94.1 mm and 57.9 mm was received during *rabi* and *summer* respectively.

In the present study, the parameters of distribution for the different distributions have been estimated by FLOOD-flood frequency analysis software. The rainfall data is the input to the software programme. The best fitted distribution of different month and season and annual were presented in Table 6. The annual rainfall in 50% probability was found to be 1514.8 mm for Deogarh district of Odisha. During *Kharif* at 50 % probability level, the rainfall is 1266.8 mm where as only 94.1 mm and 57.9 mm was received during *rabi* and *summer* respectively.

In the present study, the parameters of distribution for the different distributions have been estimated by FLOOD-flood frequency analysis software. The rainfall data is the input to the software programme. The best fitted distribution of different month and season and annual were presented in Table 1. The annual rainfall in 50% probability was found to be 1514.8 mm for Deogarh district of Odisha. During *Kharif* at 50 % probability level, the rainfall is 1266.8 mm where as only 94.1 mm and 57.9 mm was received during *rabi* and *summer* respectively, so water harvesting structures may be made to grow crops during *rabi* and *summer* to utilize the water from the water harvesting structures to increase the cropping intensity of the area. It is also observed that at 75 % probability level the July and Aug received more than 100 mm, so farmers of these area can grow crops in upland areas suitably paddy can be grown followed by any *rabi* crop in *rabi* season like mustard or kulthi in upland areas. In Fig 1 the plot between different months and amount of rainfall in different probabilities were shown, It is observed that September month gets highest amount of rainfall compared to other months. Fig 2 shows the different cropping pattern in Deogarh district as per the rainfall available in different weeks.

Table 1: Rainfall analysis of Deogarh Block at different probability levels for different months and seasons.

Months	Best-fit Distribution	RMSE Value	Rainfall at probability levels				
			90%	75%	50%	25%	10%
January	EV type III	0.07042	-	-	-	15.58	35.39
February	Log Pearson	0.0601	-	-	2.39	11.01	33.33
March	Gamma	0.05918	-	-	1.94	14.65	35.86
April	Gumbel maximum	0.06675	-	-	-	15.63	32.71
May	Pareto	0.0559	-	10.31	30.67	50.92	62.95
June	Pareto	0.04176	47.66	75.44	131.26	210.24	289.36
July	Log Pearson	0.05314	120.32	172.39	257.07	383.40	549.58
August	Log Pearson	0.05038	150.24	208.19	283.06	365.09	440.71
September	Pareto	0.05016	54.59	89.94	159.8	255.63	347.3
October	Pareto	0.03902	0.8	13.14	39.26	79.94	126.85
November	EV type III	0.07886	-	-	-	0.92	14.3
December	Pearson	0.05428	-	-	-	3.42	20.18
Annual	GEV	0.04222	1106.68	1305.33	1514.8	1704.11	1848.01
<i>Kharif</i> (June-Sep)	Log normal	0.02898	956.11	1103.61	1266.8	1423.80	1552.52
<i>Rabi</i> (Oct-Jan)	Log Pearson	0.05516	33.15	53.90	94.1	167.47	286.20
<i>Summer</i> (Feb-May)	Log Pearson	0.04125	21.44	35.68	57.9	86.97	117.97

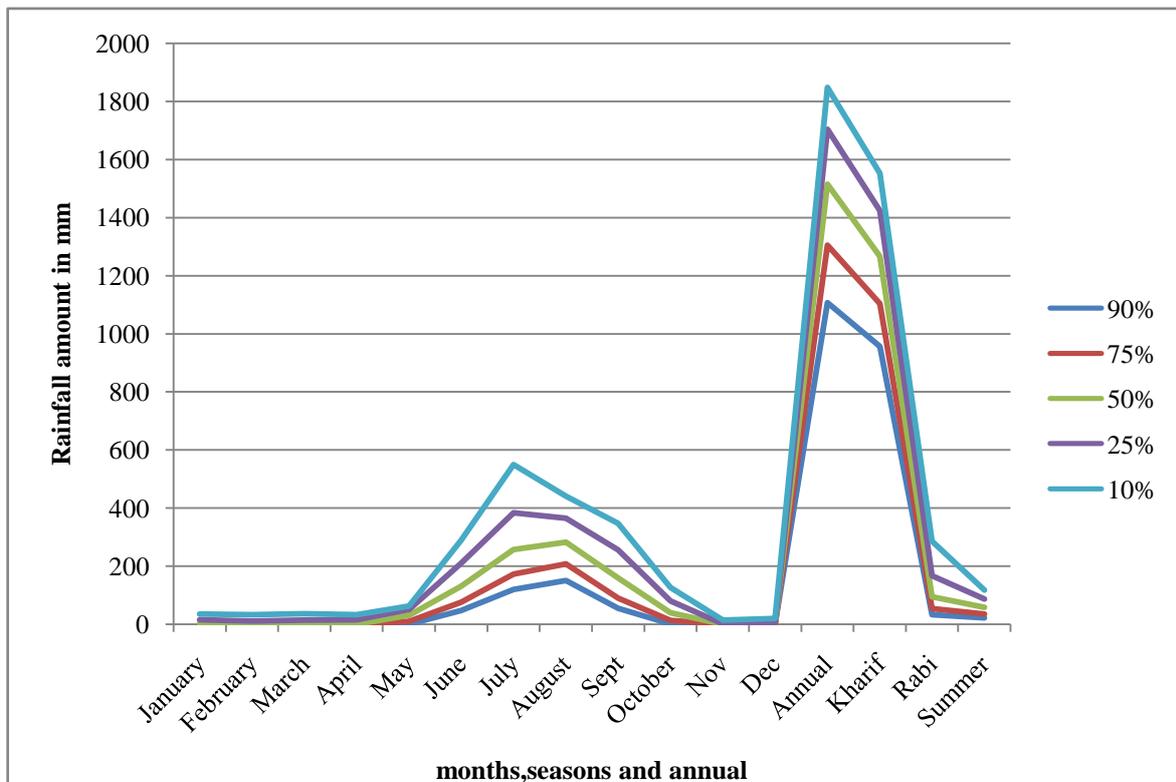


Fig 1: Rainfall at different probabilities of monthly, seasonal and annual at Deogarh block

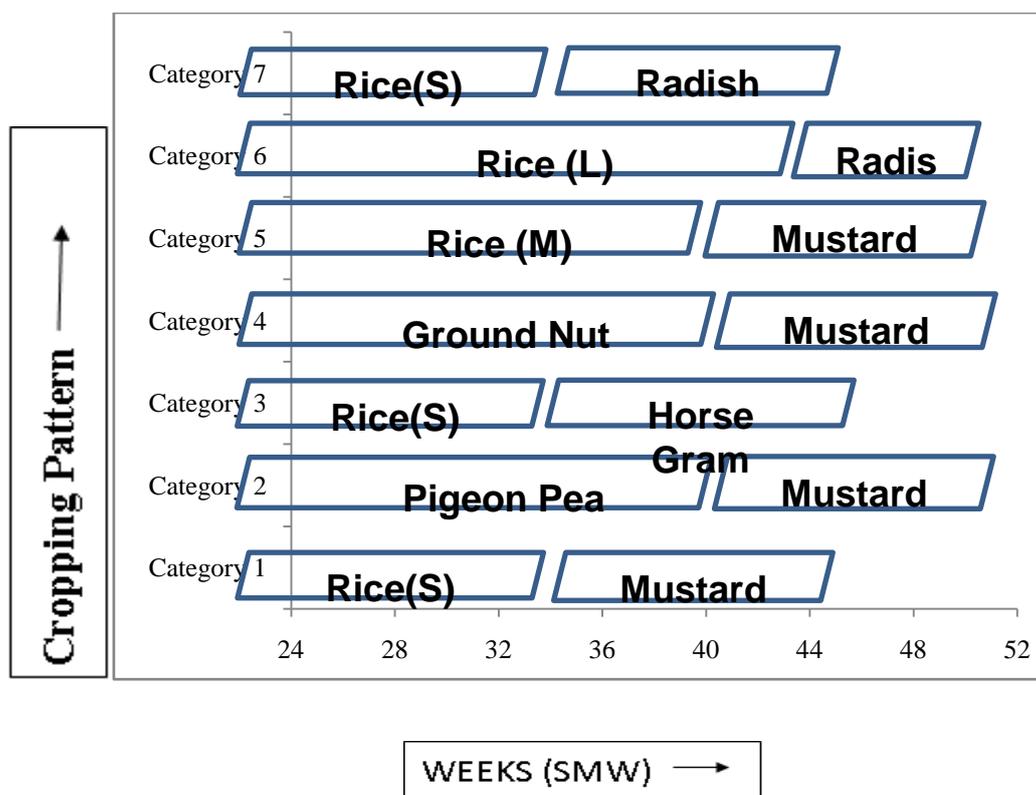


Fig. 2: Different cropping patterns for Deogarh district

Conclusion

Forecasting of rainfall is essential for proper planning of crop production. About 70% of cultivable land of Odisha depends on rainfall for crop production. Prediction of rainfall in advance helps to accomplish the agricultural operations in time. It can be concluded that, excess runoff should be harvested for irrigating post-monsoon crops. It becomes highly necessary to provide the farmers with high-yielding variety of crops and such varieties which require less water and are early-maturing in Deogarh district of Mahanadi command area of Odisha. It is also observed that at 75 % probability level the July and Aug received more than 100 mm, so farmers of these area can grow crops in upland areas suitably paddy can be grown followed by any *rabi* crop in *rabi* season like mustard or kulthi in upland areas. Annual rainfall of Deogarh district is 1514.8 mm at 50% probability level. It is observed that September month gets highest amount of rainfall compared to other months. Different cropping pattern selected may be may be practiced in this district.

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