Research Article
Open Access
CrossMark

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

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**.** Rayagada district has a total geographical area of 7584.7sq.km. Rayagada district has latitude of 26°N and a longitude of 94°20'E. The average rainfall at Rayagada district is around 1340.3mm, 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 Rayagada district. So rainfall data were collected from OUAT, Agril Meteorology Dept. from 2001 to 2017(17years) 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 Rayagada district in different months, years and seasons. It is observed that rainfall during June to Sep is slightly less than 1000mm and cropping pattern like paddy(110days) 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 Rayagada district is 1340.3mm at 50% probability level.

Keywords: rainfall, probability analysis, crop planning

Volume 3 Issue 6 - 2019

Subudhi CR,[1] Nibedita Jena,[2] Sukanya Suryavanshi,[2] Subudhi R[2]

[1]Professor, CAET, OUAT, India
[2]Ex student, CAET, OUAT, India

Correspondence: Subudhi CR, Professor, CAET, OUAT, Bhubaneswar-751003, Odisha, India, Email rsubudhi590@gmail.com

Received: November 07, 2019 | **Published:** December 26, 2019

Introduction

Rayagada district has a total geographical area of 7584.7sq.km. Rayagada district has latitude of 26°N and a longitude of 94°20'E. The average rainfall at Rayagada district is 1340.3mm, 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 Rayagada district

Thom[1] 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,[2] Jat et al,[3] Senapati et al,[4] and Subudhi et al.[5] 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.[5] Gumbel[6] Chow,[7] have applied gamma distribution with two and three parameter, Pearson type-III, extreme value, binomial and Poisson distribution to hydrological data. Sachan S et al,[8] attempted probability analysis using the rainfall data of 30 years(1976-2005) in various influencing raingauge stations viz., Damoh, Hatta, Jabera and Deori falling in Bearma basin of Bundelkhand region, Madhyapradesh. Gumbel,[6] Hershfield & Kohlar.[9] Have applied gamma distribution with two and three parameter, Pearson type-III, extreme value, binomial and Poisson distribution to hydrological data.[10]

Materials and methods

The data were collected from District Collector's Office, Gajapati district for this study. Rainfall data for17years from 2001 to 2017 are collected for the present study to make rainfall forecasting using different methods

Probability distribution functions

For seasonal rainfall analysis of Gajapati 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

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

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

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

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

Log-normal (2-parameter) distribution

The probability density is

$$p(x) = \left(1/\sigma_y e^y\sqrt{2\pi}\right)\, e^{-(y-\mu y)^2/2\sigma_y}$$

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:

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

Where $\mu, \sigma\, and\, \lambda$ 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

$$p(x) = e\int_{-\infty}^{x}\frac{a+x}{b_0 + b_1 x + b_2 x^2}dx$$

Where $a, b_0, b_1 and\, b_2$ are constants.

The criteria for determining types of distribution are $\beta_1, \beta_2 and\, k$ 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 $\mu_2, \mu_3 and\, \mu_4$ 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

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

And C_S = coefficient of skew of variate Z

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

$\overline{Z}$ = 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 $\mu, \sigma and \xi$.

The cumulative distribution function is

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

For $x \ge \mu$ when $\xi \ge 0$ and $x \le \mu - \frac{\sigma}{\xi}$ when $\xi < 0$,where

$\mu \in R$ is the location parameter, $\sigma > 0$ the scale parameter and $\xi \in R$ 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

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

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

Generalized extreme value distribution

Generalized extreme value distribution has cumulative distribution function

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

For $1+\xi(x-\mu)/\sigma>0$, where $\mu \in R$ is the location parameter, $\sigma > 0$ the scale parameter and $\xi \in R$ the shape parameter. The density function is, consequently

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

Again, for $1+\xi(x-\mu)/\sigma>0$

Gumbel's method: The extreme value distribution was introduced by Gumbel[6] and is commonly known as Gumbel's distribution. It is one of the most widely used probability-distribution functions for extreme values in hydrologic and meteorological studies. According to this theory of extreme events, the probability of occurrence of an event equal to or larger than a value x_0 is

$$P(X \geq x_0)=1-e^{-e^{-y}}$$

in which y is a dimensionless variable and is given by

$$y=\alpha(x-a)$$

$$a=\bar{x}-0.45005\sigma_x$$

Thus $y=\dfrac{1.2825(x-\bar{x})}{\sigma_x}+0.577$...... …….. (i)

Where $\bar{x}$ = mean and σ_x = standard deviation of the variate X. In practice it is the value of X for a given P that is required and such Eq. (i) is transposed as

$$y_p=-\ln[-\ln(1-\mathrm{p})]$$

Noting that the return period $T=1/\mathrm{P}$ and designating y_T =the value of y, commonly called the reduced variate, for a given T

$$y_T=-\left[\ln.\ln\frac{T}{(T-1)}\right]$$

Or

$$y_T=-\left[0.834+2.303\ log\,log\ \frac{T}{(T-1)}\right]$$

Now rearranging Eq. (i), the value of the variate X with a return period T is

$$x_T=\bar{x}+K\sigma_x$$

Where $K=\dfrac{(y_T-0.577)}{1.2825}$

The above equations constitute the basic Gumbel's equations and are applicable to an infinite sample size (i.e. $N \to \infty$).

Table 1 Rainfall analysis of Rayagada district 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	0.05662	-	-	-	13.15	32.85
February	Pareto	0.04265	-	-	-	-	10.64
March	Exponential	0.0577	-	-	11.44	34.43	64.84
April	Gamma	0.06436	-	-	22.92	68.44	130.69
May	Gumbel-max	0.03242	1.11	35.5	73.41	119.17	170.71
June	Weibull	0.0447	65	115.44	190.89	283.75	379.27
July	Pareto	0.05212	119.24	166.98	262.77	397.94	532.8
August	Log-Normal	0.03976	161.14	219.33	308.98	435.3	592.76
September	Log-Normal	0.03585	93.91	135.02	202.16	302.71	435.47
October	Pareto	0.03324	-	8.18	81.85	182.44	278.02
November	Pearson	0.04999	-	-	3.79	25.12	51.87
December	Pareto	0.06214	-	-	-	-	30.06
Annual	Pareto	0.05995	1022.03	1131.26	1340.3	1610.28	1846.79
Kharif (June-Sept)	Pareto	0.0567	699.38	830.75	1066.2	1335.35	1532.34
Rabi (Oct-Jan)	Log-Pearson	0.03913	-	52.26	125.9	219.57	313.53
Summer (Feb-May)	Pearson	0.05757	54.78	86.47	136	202.89	279.36

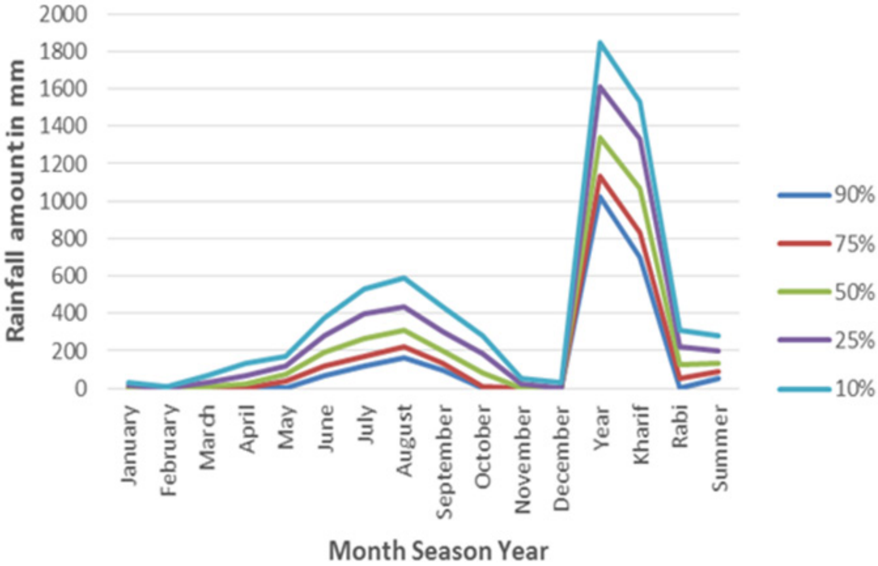

Figure 1 Rainfall at different probabilities of monthly, seasonal and annual at Rayagada block.

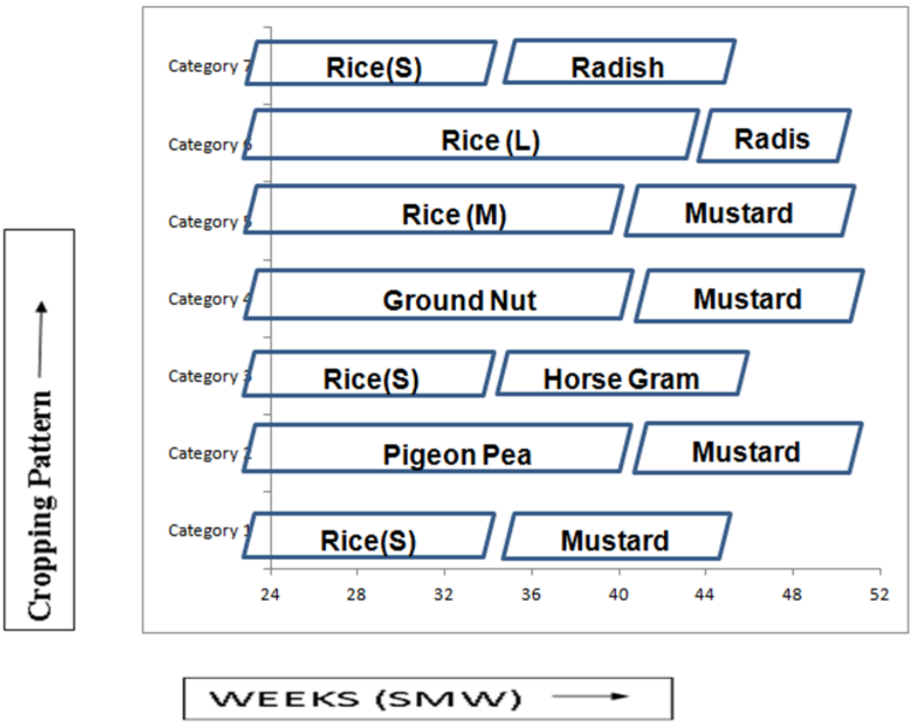

Figure 2 Different cropping patterns for Rayagada district.

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 1340.3mm for Rayagada block of Odisha. During *Kharif* at 50% probability level, the rainfall is 1066.2mm where as only125.9mm and 136.0mm 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 1340.3mm for Rayagada district of Odisha. During *Kharif* at 50% probability level, the rainfall is 1066.2mm where as only125.9mm and 136.0mm 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 1340.3mm for Rayagada district of Odisha. During *Kharif* at 50 % probability level, the rainfall is 1066.2mm where as only125.9mm and 136.0mm 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 June, July, Aug and Sept 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 Figure 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. Figure 2 shows the different cropping pattern in Rayagada district as per the rainfall available in different weeks.[11–16]

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 Rayagada district of Mahanadi command area of Odisha. It is also observed that at 75% probability level the June, July, Aug and Sept 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 Rayagada district is 1340.3mm 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.

Acknowledgments

None.

Conflicts of interest

The authors declare that there is no conflict of interest.

Funding

None.

References

1. Thom HCS. *Some methods of climatological analysis*. WMO Tech. Note. No. 81. 1966.
2. Kar G, Singh R, Verma HN. Alternative cropping strategies for assured and efficient crop production in upland rain fed rice areas of eastern India based on rainfall analysis. *Agricultural Water Management*. 2004;67(1):47–62.
3. Jat ML, Singh RV, Balyan JK, et al. Analysis of weekly rainfall for Sorghum based crop planning in Udaipur region. *Indian J Dry land agric Res & Dev.* 2006;21(2):114–122.
4. Subudhi CR. Probability analysis for prediction of annual maximum daily rainfall of Chakapada block of Kandhamal district of Orissa. *Indian J Soil Cons*. 2007;35(1):84–85.
5. Senapati SC, Sahu AP, Sharma SD. Analysis of meteorological events for crop planning in rain fed uplands. *Indian J Soil Cons*. 2009;37(2):85–90.
6. Gumbel EJ. Statistical theory of droughts. *Proceedings of ASCE*. 1954;80(439):1–19.
7. Chow VT. *Hand book of Applied Hydrology*. McGraw Hill Book Co, NewYork. 1964;8–28.
8. Sachan S,Thomas T, Singh RM. Probability Analysis of Rainfall in Bearma Basin of Bundelkhand Region of Madhya Pradesh. *International Journal of Agriculture, Environment and Biotechnology*. 2008.
9. Harshfield DM, Kohlar MA. An empirical appraisal of the Gumbel extreme procedure. *J of Geophysics Research*. 1960;65(6):1737–1746.
10. Panigrahi B. Probability analysis of short duration rainfall for crop planning in coastal Orissa. *Indian J Soil Cons.* 1998;26(2):178–182.
11. Reddy SR. *Principles of Agronomy*. 1st edition. Kalyani publication. 1999.
12. Sadhab P. Study of rainfall distributions and determination of drainage coefficient: A case study for coastal belt of Orissa. *M Tech. thesis. CAET. OUAT*. 2002;1-126.
13. Sharda VN, Das PK. Modeling weekly rainfall data for crop planning in a sub–humid climate of India. *Agricultural Water Management*. 2005;76(2):120–138.
14. Subramanya K. *Engineering Hydrology*. 23rd reprint. Tata Mc–graw Hill Publishing Company Ltd. 1990.
15. Subudhi CR, Suryavanshi S, Jena N. Rainfall probability analysis for crop planning in Anugul block of Anugul district of Hirakud command area of Odisha, India. *International Journal of Humanities and Social Sciences*. 2019;8(3):49–54.
16. Weibull W. A statistical distribution functions of wide applicability. *J Appl Mech.–Tran ASME.* 1951;18(3):293–297.