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Rainfall Probability Analysis for Crop Planning in Pratapgarh District of Rajasthan, India

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A B S T R A C T

This study was under taken in the P.G. thesis work in the Dept. Of SWE, CTAE, MPUAT, Udaipur during the year 2021**.** Pratapgarh district has latitude of 24° 03" N and longitude of 74° 47" E. From the rainfall analysis, the chance of getting 1215.6 mm and 912.7 mm rainfall at 50% and 75% probability respectively was found to be in the district with maximum rainfall. The crop selection depends on the areas shown in Iso-probable map for Rajasthan during monsoon months from June to October. At 50 % probability level the crop success is 2 in every 4 years and in 75 % probability level the crop success is 3 in every 4 years.

Introduction

There is considerable variation in the rainfall pattern throughout the state of Rajasthan. On the basis of rainfall the state has been broadly divided into three main climatic regions: arid or desert region, semi arid region and sub-humid region on the basis of rainfall. Pratapgarh district receives highest amount of rainfall in the state. The annual average rainfall at Pratapgarh district was found to be 1378.14 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, monthly and weekly rainfall data of Pratapgarh districts. Many studies are available on the observed trends and variability of rainfall and also extreme rainfall events, but all the studies are based on past 100 years or more data and also the recent years are not included. In the study, 30 years (1989-2019) rainfall data was taken for the probability analysis and crop planning was done using 50-75% probability level. *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.

Materials and Methods

The data were collected from www.water.rajasthan.gov.in, for this study. Rainfall data for 30 years from 1990 to 2019 are collected for the presented study to make rainfall forecasting through different methods

Probability Distribution Functions

For seasonal rainfall analysis of the districts, 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

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

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:

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

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

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

where a, b_0, b_1 and b_2 are constants.

The criteria for determining types of distribution are 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

$$z = logx$$

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

$\sigma_z =$ 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

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

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

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

Or

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

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

Results and Discussion

This study deals with the overall rainfall distributions at different probability level of Pratapgarh district of Rajasthan. Probability distribution enables us to obtain estimates of the probability that certain event may occur, or estimate the variability of occurrence. Selection of a probability distribution which gives the best fit to the observed rainfall enables prediction of design rainfall for a given AEP (Annual exceedence probability), urban infrastructure planning and design of culverts drainage systems etc. In the study 10%, 25%, 50%, 75%, 90% probability analysis of the weekly, monthly, seasonal and annual rainfall was carried out using the Flood software.

The main aim of the study is to suggest reliable crop planning policies for maximum returns to the farmers, development of optimal water allocation policies and management strategies to bridge the gap between water needs and optimal water supply under possible drought conditions in the state.

The probability and frequency of rainfall pattern is one of the important issues for long term planning of agricultural operations, irrigation schemes as well as for the watershed management. The best fit distribution was obtained for Pratapgarh district of Rajasthan considering the least RMSE and mean error values of the distributions obtained in the outcome of the operation which has been carried out in the software.

Pratapgarh district has latitude of 24° 03" N and a longitude of 74° 47" E. The average rainfall in the district is around 1378.137 mm, most of the rainfall occurred during *kharif*. The annual rainfall in 50% probability was found to be 1215.65 mm for Pratapgarh district of Rajasthan.

During *kharif* at 50% probability level, the rainfall is 1120.6 mm where as only 12.11 mm and 1.5 mm was received during *rabi* and summer respectively. Crops are most sensitive to water deficit during emergence of seedling, flowering and early yield formation and least sensitive to water shortage in late season stage. Crops grown for fresh leaves and fruits are more sensitive than those grown for seed or dry fruits. Selection of crop and area under each crop are based mainly on suitable of climate and availability of other input in crop production. Cost of irrigation system and its management is also considered.

The quantity of water to be supplied on monthly, 10 days or weekly basis was decided. Optimum use of rainfall during crop season and available soil moisture storage from pre season rain and reducing peak requirement in water by shifting sowing dates are some of the other factors which are to be considered for cropping system and water management.

The fig 1 shows graphical representation of rainfall at different probability levels.

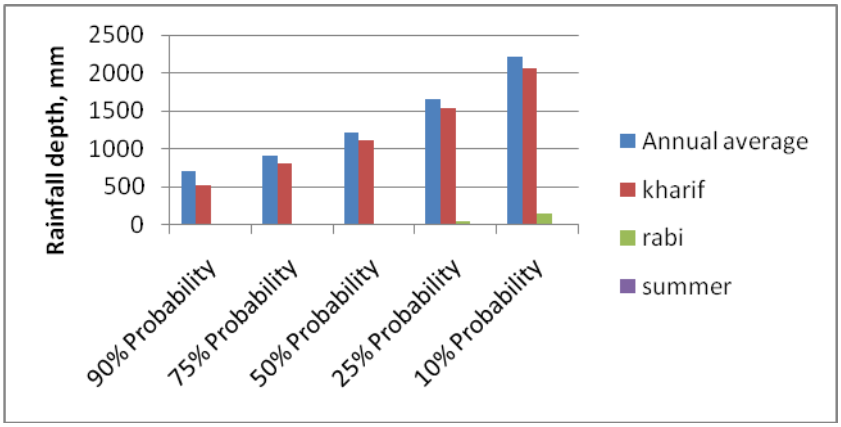
In the present study, the parameters of distribution for the different distributions have been estimated by FLOOD-flood frequency analysis software.

Table.1 Rainfall analysis of Pratapgarh district at different probability levels

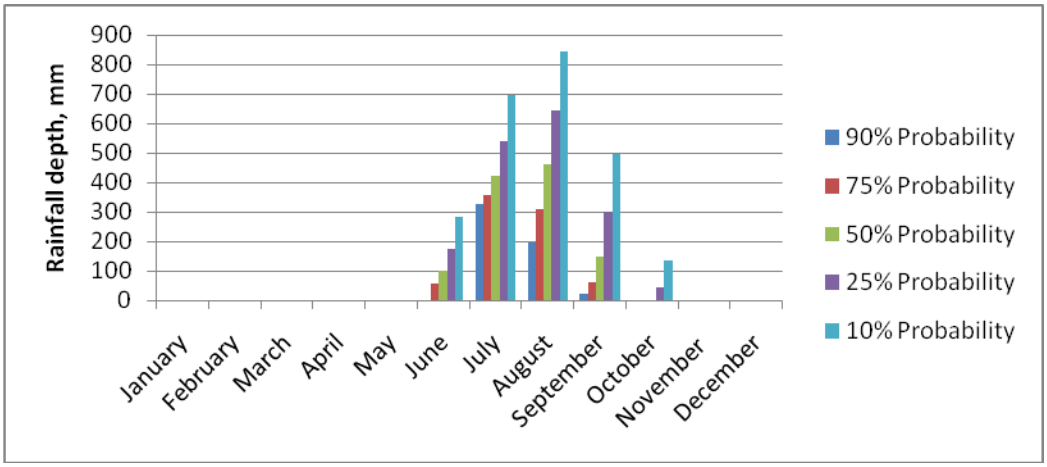
Annual average/Seasons/Months/SMW	Best fit distribution	Mean Error	Rainfall at different probability					
			RMSE	90%	75%	50%	25%	10%
Annual average	GEV	0.04	0.54	709.73	912.73	1215.65	1647.09	2213.08
kharif	gev	0.05	0.05	515.56	807.92	1120.63	1533.76	2058.68
rabi	lognormal	0.03	0.04	0	0	12.11	51.67	152.65
summer	pareto	0.05	0.07	0	0	1.21	10.61	20.49
January	-	-	-	-	-	-	-	-
February	-	-	-	-	-	-	-	-
March	-	-	-	-	-	-	-	-
April	-	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-	-
June	logpearson	0.05	0.05	0	55.82	101.55	172.32	283.46
July	pareto	0.05	0.06	326.59	356.44	423.28	538.95	694.66
August	log 3 par	0.06	0.07	196.01	308.82	459.82	643.45	842.57
September	exponential	0.06	0.07	22.71	62	149.39	298.77	496.24
October	gamma	0.05	0.07	0	0	0	41.75	136.35
November	-	-	-	-	-	-	-	-
December	-	-	-	-	-	-	-	-
SMW 25	lognormal	0.04	0.05	0	0	13.14	43.63	112.5
SMW 26	gev	0.06	0.06	0	0	37.19	120.02	208.24
SMW 27	lognormal	0.04	0.05	0	5.76	24.4	90.12	281.84
SMW 28	pareto	0.04	0.05	5.27	33.06	94.64	-	183.35
SMW 29	exponential	0.06	0.07	3.14	34.36	103.79	222.48	379.37
SMW 30	pareto	0.02	0.03	8.57	39.85	95.39	157.85	202.44
SMW 31	logpearson	0.06	0.08	0.28	4.02	20.66	82.35	256.28
SMW 32	logpearson	0.05	0.06	13.51	32.86	65.73	132.17	258.03
SMW 33	gamma	0.04	0.05	1.39	22.25	77.92	184.12	351.03
SMW 34	logpearson	0.04	0.04	3.46	13.81	48.23	128.74	254.5
SMW 35	ev 3	0.07	0.08	0	0	42.27	135.08	233.08
SMW 36	pareto	0.04	0.06	0	2.72	43.23	102.48	164.77
SMW 37	logpearson	0.08	0.09	0	0	8.04	50.66	180.16
SMW 38	ev 3	0.07	0.08	0	0	0	37.6	82.84

Fig.1 Rainfall at different probabilities of (a) annual and seasonal (b) monthly and (c) SMW at Pratapgarh District

(a)



(b)



(c)

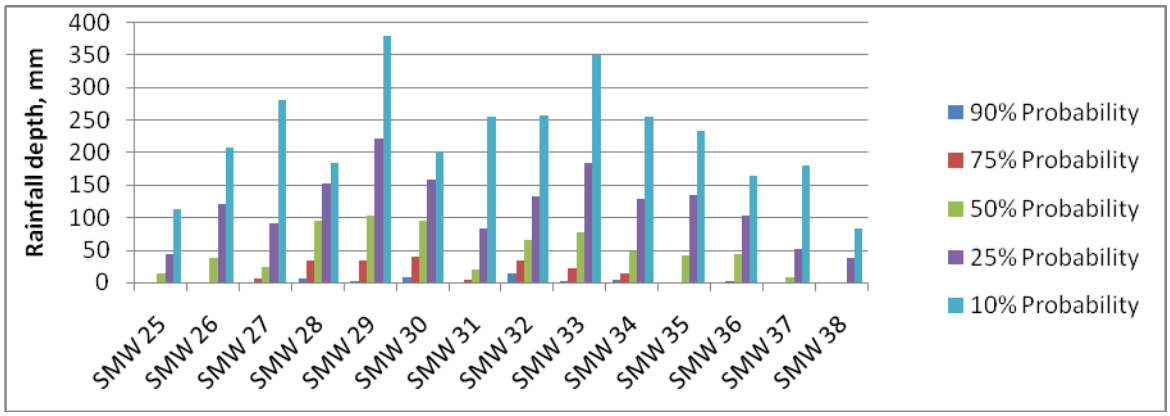


Fig.2 Crop Water Requirement vs. Water availability at 50-75% probability for pulses and groundnut

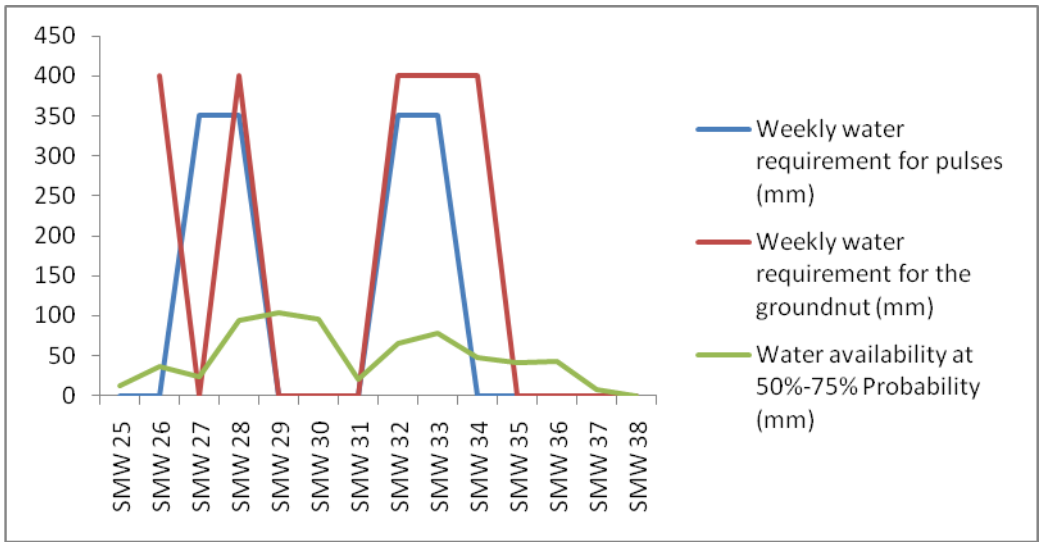
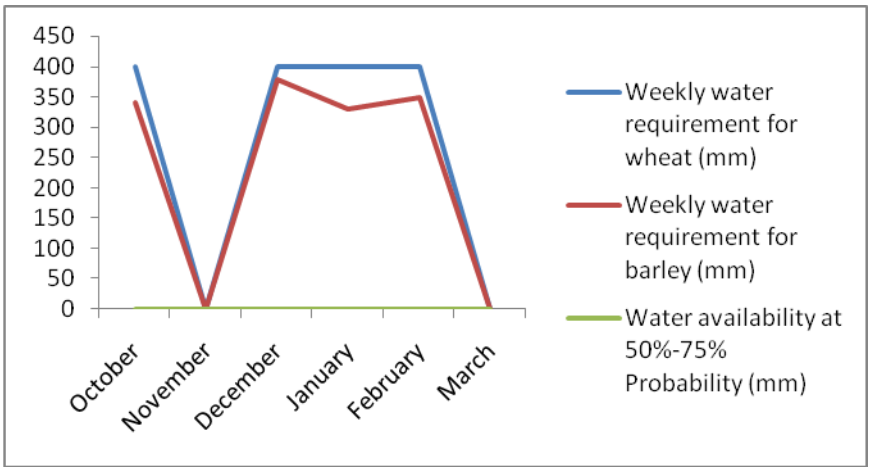


Fig.3 Crop Water Requirement vs. Water availability at 50-75% probability for wheat and barley



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 at 50% probability was found to be 1215.65 mm for *Pratapgarh* district of Rajasthan. During *Kharif* at 50 % probability level, the rainfall is 1120.63 mm where as only 12.11 mm and 1.11 mm was received during *rabi* and *summer* respectively, so water harvesting structures may be made to grow crops during *rabi* and *summer* to utilise 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 August received more than 100 mm.

Selection of crop in *kharif*

Mostly pulses are grown in rainfed conditions. In summer, redgram, blackgram, greengram are grown as irrigated crop which need 3 to 4 irrigation at critical stage like germination, flowering and pod formation. Water

requirement for pulses is around 350 mm (i.e. after 20-25 days of sowing, podding stage and 50-65 days after sowing, and flowering stage). 4 number of irrigation is provided to the crop. Thus, the water requirement at different time period and the water availability at 50%-75% probability rainfall is plotted in the graph below for pulses and groundnut for the selection of better crop for the district and for planning of supplement irrigation and water management.

Due to the low water requirement for pulses as compared to that of groundnut, it is selected as the suitable crop for the district.

Selection of crop in *rabi*

Wheat crop requires minimum of 5 irrigations at the following critical stages (i.e. Immediately after sowing, crown root initiation, active tillering stage, flowering stage, grain filling stage;15-20 DAS, 35-40 DAS, 50-55 DAS, 70-75 DAS respectively). Thus, the water requirement at different time period and the water availability at 50%-75% probability rainfall is plotted in the graph below for barley and wheat and for planning of supplement irrigation and water management.

Although weekly water requirement for wheat is slightly more than barley (i.e. by 50mm of water), but due to the high local demand of the crop, wheat is selected for the cultivation in the district.

Pratapgarh receives 709.73 mm, 912.73 mm, 1215.65 mm, 1647.09 mm, and 2213.08 mm of rainfall at 90%, 75%, 50%, 25% and 10% probability level respectively. The district receives highest in state and GEV was found as the best fit distribution. Forecasting of rainfall is essential for proper planning of crop production. In the upland areas suitably redgram, blackgram, greengram can be grown followed by mustard, wheat or gram in *rabi* season. It is observed that July month gets highest amount of rainfall compared to other months at 75% probability level. In irrigated area the water harvesting pond may be constructed to harvest *kharif* water vegetables may be practised by using drip and sprinkler irrigation methods. As per the SMW analysis SMW-25 to 34 are considered wet weeks.

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