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Rainfall probability analysis for crop planning in Raipur region of Chhattisgarh plain

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Abstract
Probability analysis of rainfall offers a better scope for predicting the minimum assured rainfall to help in crop planning in rainfed regions. An attempt has been made to evaluate rainfall distribution patterns i.e. weekly, seasonal and annual rainfall, based on 40 years (1971-2010) data of raipur, Chhattisgarh at BRSM College of Agricultural Engineering and Technology, Indira Gandhi Krishi Vishwa Vidyalaya, Mungeli, Chhattisgarh. Expected weekly, monthly, seasonal, and annual rainfall values at different probability levels were determined by using Normal Distribution Function. The analysis showed that at 75% probability level the highest rainfall 25.83 mm received by 33rd week and lowest rainfall received by 39th week i.e. 7.41 mm. The climatic season are varied in nature and found that at 75% probability the monsoon season received highest rainfall i.e. 294.74 mm, and lowest rainfall received by season winter i.e. 9.71 mm. At 70% probability Rabi season received the lowest rainfall 13.61mm which contributed the 1.15% of the average annual rainfall; the highest rainfall received at this probability level by *Kharif* season 315.79 mm and contributed the 26.81% of average annual rainfall. The values of annual rainfall were estimated 125.11, 262.99, 338.89, 420.99, 601.99, 816.99, 1081.69, 1632.79, 1900.99 and 2711.99 mm at 90, 80 75, 70, 60, 40, 25, 20 and 10% probability level, respectively. At 70% probability enough rainfall is available for growing high value fruit crops although supplemental irrigation is required for *Kharif* crops.

Keywords: Rainfall, crop planning, probability analysis, Chhattisgarh, Rainfed

Introduction
Due to variation in rainfall distribution it is imperative to determine the probability of rainfall recurrence. Probability and frequency analysis of rainfall data enable us to determine the expected rainfall at various percent chances. Probability analysis is the most reliable method to predict occurrence of future rainfall events based on past behavior of rainfall. Rainfall analysis is of great important for developing and modifying the crop management practices for sustainable production system. More than 80% of the average annual rainfall of Raipur occurs during South West monsoon. Due to uneven distribution of rainfall and absence of suitable *in-situ* rainwater harvesting practices, the district is affected by water scarcity during rabi and summer seasons every year. Sheet and rill erosions are also very severe and have resulted in vast stretches of wasteland. With a view to harvest the rainfall in situ and control soil erosion, several watershed development projects are operative in the district under Integrated Watershed Development Programme (IWMP), Integrated Wasteland Development Project (lWDP) and Mahatma Gandhi National Rural Employment Guaranty Scheme (MNREGA). Construction of rainwater harvesting structures, nalabund/ earthen embankments and masonry check dams etc., is an important activity in these programme. This activity is presently done without ascertaining the amount of rainfall and corresponding expected runoff for the desired return period. Due to this fact, many of the mechanical soil conservation structures, constructed with huge investment and labour are failing occasionally due to flash floods. However, analysis of rainfall data for computation of expected rainfall for the desired frequency and consequent excess rainfall is required for the safe design of any structure. Subudhi *et al*. (2012) [6] conducted a study on probability analysis of rainfall for crop planning in Kandhmal distric of Orrisa. They found that the available rain water for crop is assured at 75% probability levels. Sharma and Dubey (2013) [4] conducted probability analysis of rainfall during rainfall data (2000-2010), for semi arid region of Uttar Pradesh. Khandelwal et al. (2013) [3] reported temporal rainfall distribution affecting crops and its analysis for harvesting. Singh *et al.* (2016) [5] made an attempt to evaluate rainfall distribution based on 13 years (2000-2012) data of Shivri, Lucknow, Uttar Pradesh. Keeping this in view, an effort was made in the present investigation to interpret daily, weekly, monthly, seasonal and annual rainfall of 40 years (1971-2010) data of Raipur, Chhattisgarh in simple and meaningful form to make it more useful for prediction of rainfall amounts at different probability level.

Materials and Methods

Raipur district covers an area of 13083 km^2 and lies between North latitudes 19° 46' and 21° 50' and East longitudes 81° 25' to 83° 16'. Physiographically, the district is divided into three unit's viz. Chhattisgarh plain, eastern and south eastern undulating and hilly tract and southern hilly range. The land use pattern indicates that 42% of the area is occupied by the agricultural land. The district has a tropical climatic condition. The entire district falls under Mahanadi Basin- main tributaries being Seonath, Jok & Tel. In the Raipur region there are wide variations in the climate. Raipur has a tropical wet and dry climate, temperatures remain moderate throughout the year, except from March to June, which can be extremely hot. The winter commences from November and last till the end of February. The summer season beings from March and continues till the second week of June. Monsoon season commences from middle of June and remains till the end of the September. The information about normal values of climatic parameters was taken from Meteorological Department of College of Agriculture, IGKVV, Raipur and are presented in Fig. 1.

Analysis of Rainfall Data

Daily, weekly, monthly, seasonally and annual rainfall data of past 40 years of Raipur were used in probability analysis. These data were used to fit in appropriate probability distribution in order to draw inference on probable future behavior of such events.

Probability of Exceedence of Rainfall

Probability of rainfall at different level was computed by using the function NORMDIST (MS Excel 5.0) was used to determine the expected amount of rainfall at different probability level. The equation used to compute the normal probability density function from the mean and standard deviation is given below (Equation 1):

$$f(x,\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(x-\mu)^2}{2\sigma^2} \right] \quad \ldots (1)$$

Where, x = Variable for which the distribution is required.
μ = Arithmetic mean of the distribution
σ = Standard deviation of the distribution
The equation (1) was used to estimate the expected amounts of rainfall at different probabilities of exceedence. The expected amount of rainfall was worked out at weekly, seasonal and annual time intervals.

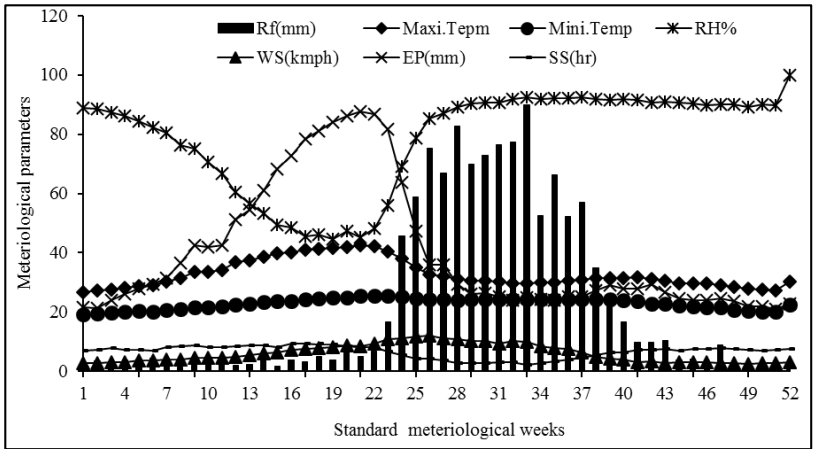

Fig 1: Variation in meteriological parameters

Results and Discussion

Rainfall Probability Estimation

Weekly rainfall probability estimation

The past forty years rainfall data have been analyzed and its weekly probability of occurrence was predicted and is presented in Table 1. This prediction helps to optimize choice of crops, sowing date and irrigation scheduling of different crops to be cultivated and efficient use of rainwater in rainfed areas for getting maximum production. In weekly rainfall probability estimation we mainly considered the monsoon season weeks (23rd to 39th). In probability estimation the values of rainfall decrease with increase the probability level (Table 1). It shows that the 90% probability received lowest rainfall and 70 percent probability is on the top followed by the curve of higher probabilities. At 75% probability level the highest rainfall 25.83 mm received by 33rd week and lowest rainfall taken by 39th week i.e. 7.41 mm. Similarly for 70, 80 and 90 percent probability the lowest values of rainfall are 9.19, 5.75 and 2.73 mm which are found by 39th week and highest values of rainfall received by 33rd weeks are 32.11, 20.10 and 9.49 mm, respectively.

Table 1: Expected values of rainfall at different probability levels during monsoon weeks.

SMW	Probability level									
	90%	80%	75%	70%	60%	50%	40%	30%	20%	10%
23	1.8	3.8	4.8	6.0	8.6	11.7	15.5	23.3	27.1	38.9
24	4.9	10.2	13.2	16.4	23.4	31.7	42.0	63.4	73.7	105.5
25	6.2	13.2	16.9	21.0	30.1	40.8	54.0	81.6	94.8	135.7
26	8.0	16.9	21.7	27.0	38.5	52.2	69.0	104.4	121.5	174.1
27	7.1	14.9	19.3	23.9	34.2	46.4	61.5	92.9	108.1	154.9
28	8.8	18.4	24.3	29.5	42.2	57.2	75.7	114.5	132.9	190.9
29	7.4	15.6	20.1	24.9	35.7	48.4	64.1	96.8	112.6	161.2
30	7.7	16.3	21.0	26.1	37.3	50.6	66.9	101.2	117.5	168.3
31	8.1	17.1	22.0	27.3	39.0	53.0	70.1	105.9	123.0	176.4
32	8.2	17.3	22.2	27.7	39.5	53.6	71.0	107.2	124.7	178.2
33	9.5	20.1	25.8	32.1	45.9	62.2	82.3	124.5	144.9	207.6
34	5.6	11.8	15.1	18.7	26.3	36.4	48.1	72.7	84.4	121.2
35	7.0	14.8	19.0	23.6	33.8	45.9	60.7	91.7	106.7	152.9
36	5.5	11.6	15.0	18.6	26.6	36.1	47.8	72.3	84.0	120.1
37	6.0	12.7	16.4	20.4	29.1	39.5	52.3	79.0	92.0	131.7
38	3.7	7.8	10.0	12.5	17.8	24.2	32.0	48.3	56.1	85.4
39	2.7	5.8	7.4	9.2	13.2	17.9	23.6	35.7	41.5	59.6
40	1.8	3.7	4.8	6.0	8.6	11.6	15.3	23.2	27.0	38.6
41	1.0	2.2	2.8	3.5	5.0	6.8	9.0	13.5	15.8	22.6
42	1.1	2.2	2.9	3.5	5.1	6.9	9.1	13.7	16.0	22.9

The rainfall should be utilized for growing rainy season crops like direct sown rice, soya bean, black gram, green gram and pigeon pea in second week of June with commencement of south west monsoon in these regions. The higher amount of rainfall could be utilized for rice transplanting starting from the first fortnight of July. The advantages of growing crops in first fortnight of June were that it could be harvested within September when the winter rainfall is uncertain and erratic. Residual moisture in medium and low land should properly be utilized for growing second crop under rainfed conditions.

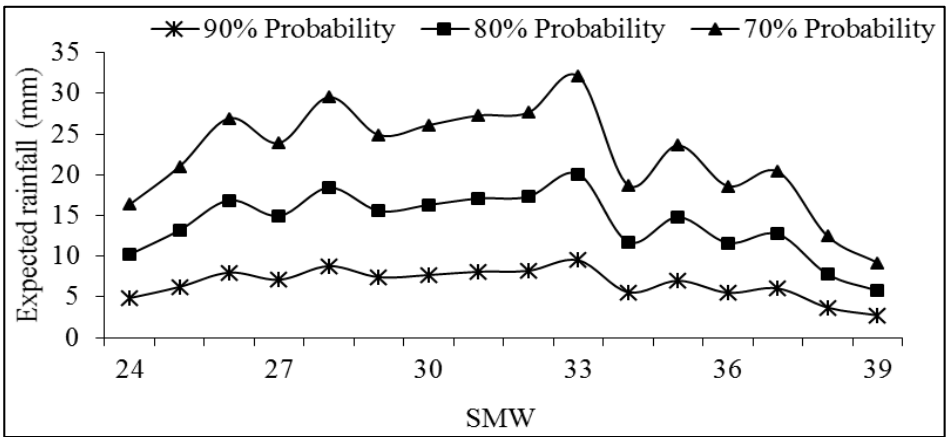

Fig 2: Crop seasonal expected rainfall at different probability level

Seed sowing in nursery in the Raipur region generally takes place immediately after imitation of monsoon (23-25 SMW). The available amount of rainfall during this period ranges from 4.84 to 16.94 mm. If available rainfall at nursery stage is compared with the evaporation, it is found that the availability of rainfall is considerably less than the evaporation ultimately evapotranpiration demand of rice crop. Hence, supplemental irrigation will be required at nursery stage. Transplanting is carried out around 27-28th SMW. It can be seen that at seedling stage the available amount of rainfall at 75% probability is 19.27mm during 27th SMW and 24.30 mm during 28th SMW where as the EP is 35.92 mm and 29.35 mm during 27th and 28th SMW, respectively. This shows that available rainfall is not quite enough to satisfy the losses demand during seedling stage of rice crop and supplemental irrigation will be required. Reproductive stage is observed during 35–40 SMW in this region. This is the most sensitive stage of rice crop with regard to water availability. Total EP (evaporation) requirement at this stage is 182.54 mm (Fig 2), where as the chances of available total rainfall at 75 percent probability of exceedence is 93.65 mm (Table 1). This means that the rice crop at this stage may experience severe drought and it will be necessary to provide supplemental irrigation from storage in water harvesting system. Similar interpretations for non-rice crops revealed that in general, the rainwater availability at 75 percent probability of exceedence fell short of EP ultimately ET requirements at reproductive stage.

At 75% chance of weekly rainfall, it is observed that for rabi season, there is no definite rainfall, which may cause of failure of rabi crops without irrigation facilities. Therefore, planning of rabi crops on the basis of 75% probability is not possible. At 50% probability, there is a 50% chance of crop failure. Therefore, crops are not possible without irrigation facilities. If the provision of water harvesting is made and stored even for single irrigation, oilseed (rapeseed/mustard) pulse crops and other low water requirement can be grown in rainfed area of Raipur region. High value winter crops could be grown only with supplemental irrigation during winter season, staring from the first week of November.

Monthly rainfall probability estimation

The month-wise rainfall variation at different probabilities (Table 2), it is clear that the curve for 75 percent probability is on the top followed by the curve of higher probabilities. It is clear from the data in Table 2 that it more than 93 mm of rainfall per month can be expected in the months of July and August, whereas during the period from October to May, the value of expected rainfall at different probabilities is less at 75 percent probability level.

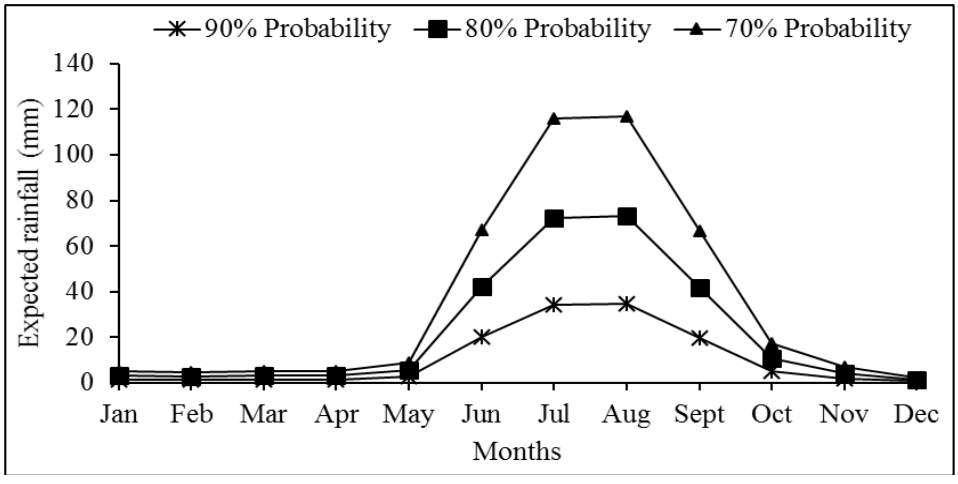

Fig 3: Monthwise expected rainfalls at different probability level

The expected rainfall amount at 70% probability is more than 100 mm in the months of July and August. Hence this would be helpful for collection of surface runoff during this excess rainfall months and efficient use of harvested rainwater during the subsequent dry period. Therefore both the July-August and October-May are critical periods from the irrigation planning point of view. A better idea of rainfall distribution can be had by studying percentage rainfall distribution for different months at different probabilities (Table 2). From the data, it is clear that the months of July and August contributed to the maximum of 27.47% and 27.77%, respectively to the total expected annual rainfall at 75 percent probability level.

Table 2: Prediction of monthly, seasonal and yearly rainfall (mm) at different probability level.

Month	Probability level									
	90%	**80%**	**75%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
Jan	1.5	3.1	4.0	5.0	7.1	9.6	12.7	19.2	22.3	31.9
Feb	1.1	3.0	3.8	4.8	6.8	9.2	12.2	18.4	21.4	30.6
Mar	1.5	3.1	4.0	4.9	7.1	9.6	12.7	19.2	22.3	31.9
Apr	1.5	3.1	4.1	5.0	7.2	9.8	12.9	19.5	22.7	32.5
May	2.6	5.4	7.0	8.7	12.4	16.8	22.3	33.6	39.1	56.0
Jun	19.9	42.1	54.0	67.1	96.0	130.4	172.4	260.3	302.1	433.6
Jul	34.1	72.3	93.1	115.8	165.6	224.9	297.3	448.7	522.4	747.6
Aug	34.5	73.1	94.1	117.1	167.1	227.0	300.0	453.5	528.0	754.6
Sept	19.6	41.5	53.5	66.4	95.0	129.0	170.7	257.7	299.9	429.6
Oct	5.2	10.9	14.0	17.4	24.9	33.7	44.6	67.3	78.3	112.0
Nov	2.0	4.3	5.5	6.9	9.8	13.3	17.6	26.6	30.9	44.2
Dec	0.7	1.5	1.9	2.3	3.4	4.5	6.0	9.1	10.6	15.1
Climatic season										
Summer	5.6	11.7	15.0	18.6	26.7	36.2	47.8	72.3	84.0	120.1
Monsoon	109.0	229.1	294.7	366.0	524.0	710.7	940.2	1420.2	1650.1	2360.9
Post monsoon	6.6	13.9	17.9	22.2	31.9	43.2	57.0	86.2	100.3	143.8
Winter	3.6	7.6	9.7	12.1	17.3	23.4	31.0	46.8	54.5	77.9
Cropping seasons										
Zaid	29.4	62.2	80.1	99.4	142.7	193.2	255.8	386.1	449.0	641.9
Kharif	94.0	198.1	254.7	315.8	453.0	614.0	812.0	1227.2	1426.0	2046.9
Rabi	5.0	10.6	13.6	16.9	24.2	32.8	43.4	65.6	76.3	109.3
Annually										
Yearly	125.1	263.0	338.9	421.0	602.0	817.0	1081.7	1632.8	1901.0	2712.0

Climatic seasonal rainfall probability estimation

The past forty years data were analyzed for climatic season and probability of occurrence was predicted (Table 2). The climatic season are varied in nature. From analysis, it is clear that at 75% probability the monsoon season received highest rainfall i.e. 294.74 mm, and lowest rainfall received by season winter i.e. 9.71 mm. Hence this would be helpful for collection of surface runoff during this rainy season and efficient use of harvested rainwater during the subsequent dry period of winter and summer season. From Fig. 3 we can see clear that the curve for 70 percent probability is on the top followed by the curve of higher probabilities. The monsoon season contribute 31.07% of the average annual rainfall at 70% probability and 1.025% contributed by winter at 70% probability.

Cropping seasonal rainfall probability estimation

In cropping seasonal analysis of rainfall at various probability levels, it is found that the values of rainfall reduced with increase the probability level. The 70% probability level most considered for agricultural planning. From Table 2 we can see clear that the curve for 70 percent probability is on the top followed by the curve of higher probabilities. At 70% probability *Rabi* season received the lowest rainfall 13.61mm which contributed the 1.15% of the average annual rainfall; the highest rainfall received at this probability level by *Kharif* season 315.79 mm and contributed the 26.81% of average annual rainfall. The excess rainfall during the *Kharif* season would be scope to harvest excess amount of rainwater and recycling of harvested rainwater as life saving irrigation at critical stages of crop growth during dry periods.

Annual Rainfall probability estimation

Probability distribution of annual rainfall is important to predict the relative frequency of occurrence of a given amount of annual rainfall with reasonable accuracy. It is clear from the Fig 3 the values of rainfall reduced with increase the probability level. The values of rainfall were estimated 125.11, 262.99, 338.89, 420.99, 601.99, 816.99, 1081.69, 1632.79, 1900.99 and 2711.99 mm at 90, 80 75, 70, 60, 40, 25, 20 and 10% probability level, respectively (Table 2). The percentage contribution of expected rainfall are 10.62, 22.33, 28.77, 35.74, 51.11, 69.37, 91.84, 138.63, 161.40 and 230.26% at 90, 80 75, 70, 60, 50, 40, 25, 20 and 10% probability level, respectively. Department (IMD) an area/region is considered to be drought affected if it receives seasonal/yearly total rainfall less than 75% of its normal value (Appa Rao, 1986) [1]. Years of which contribution are less than 75% of average annual rainfall would be drought. From the observation it is clear that the expected amount of rainfall at probability level higher than 50% are less than 75% of average annual rainfall. Hence at these probability levels the years would be considered as drought year.

Conclusions

On the basis of rainfall analysis of rainfall data of Raipur, it can be inferred that at 75% probability level the highest rainfall 25.83 mm received by 33rd week and lowest rainfall received by 39th week i.e. 7.41 mm. The climatic season are varied in nature and found that at 75% probability the monsoon season received highest rainfall i.e. 294.74 mm, and lowest rainfall received by season winter i.e. 9.71 mm. At 70% probability *Rabi* season received the lowest rainfall 13.61mm which contributed the 1.15% of the average annual

rainfall; the highest rainfall received at this probability level by *Kharif* season 315.79 mm and contributed the 26.81% of average annual rainfall. The values of annual rainfall were estimated 125.11, 262.99, 338.89, 420.99, 601.99, 816.99, 1081.69, 1632.79, 1900.99 and 2711.99 mm at 90, 80 75, 70, 60, 40, 25, 20 and 10% probability level, respectively. Hence the valuable information obtained from the analysis of rainfall in present study can be used for crop planning, designing of soil and water conservation structure in the Raipur region.

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