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Prediction of Rainfall at Different Probability Levels for Estimation of Drought Pattern in Etawah District of Uttar Pradesh

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A B S T R A C T

Droughts happen when there is not enough rainfall for a longer period of time. When there is so little precipitation (rainfall, snow etc.) the whole region starts to dry out. Sometimes a drought take decades to develop fully and they are very difficult to predict. Rainfall data of 15 years (2001-2015) based on standard weeks was analyzed for Etawah district of Uttar Pradesh. The monthly maximum rainfall at different probability levels was calculated using Gumbel's Probability method. The daily rainfall data series was divided into annual, seasonal, monthly and weekly data series. A year was divided into three seasons i.e. monsoon (June to September), winter (October to January) and summer (February to May). The last day of every year (365th day) and last two days of a leap year are accounted as 52nd week. It was observed that the maximum number of drought weeks during the 15 years period was 15 times during the 19th week while, the minimum numbers of drought weeks was 6 times which were found in the 33th and 35th standard week. The maximum number of surplus weeks during the 15 years period was 4 during 27th, 32th and 34th week however, the minimum numbers of surplus weeks i.e. 0 were found in the 6th and 19th standard week of the year.

Introduction

The word "drought" is a relative term, and is defined differently by different regions and sources. Webster's Dictionary defines drought as "a long period of no rain"; though this is an inadequate definition for the water supply industry. Droughts are major natural disasters for many parts of world. Dry areas, where precipitation pattern is markedly seasonal, or is otherwise highly variable, are the most susceptible. Unlike most natural disasters, drought onset is difficult to identify. Meteorological and agricultural drought occurrences along time and space take place randomly and therefore their scientific quantifications are possible by the probabilistic methods. Drought is complex

event which may impair social, economic, agricultural and other activities of society. Drought means scarcity of water, which adversely affects various sectors of human society, e.g. agriculture, hydropower generation, water supply, industry (Kasa *et al.,* 1999). The greater the demand placed on an area's water resources, the more serious is the drought (Sudhishri *et al.,* 2004).

Materials and Methods

The study was conducted in Etawah district of Uttar Pradesh in the year 2016. Etawah district of Uttar Pradesh lies entirely in the Gangetic plain. For the pesent study, the rainfall data were collected for a period of 15 year (2001-2015) from Meteorological Department, Etawah (U.P.). Data were tabulated and analyzed using percentage, rank order and Gumbel Distribution Method of calculated the mean, standard deviation and probability level.

The week was classified as drought week in which rainfall received less than 50 percent of average rainfall. (Ramdas and Malik., 1940). The month was classified as drought month in which precipitation received was less than 50 per cent of average monthly rainfall. (Aher *et al.,* 2012).

Results and Discussion

The rainfall was categorized based on weekly, monthly and annual rainfall data for drought, normal and surplus conditions. The present study was conducted for planning and management of irrigation in Etawah district of Uttar Pradesh. The irrigation requirement of different crops was determined using various climatological and effective rainfall data of the command area. Estimation of weekly rainfall probabilities plays a vital role in crop planning.

Weekly rainfall

Probability analysis of rainfall for 15 years was done using Weibull's method for calculating the rainfall for drought, normal and surplus conditions. The weekly distribution of rainfall is shown in the Table 1 and graphically represented in Figure 1. The maximum weekly rainfall during 15 years period was 52.64 mm in the 30th week while minimum weekly rainfall was 0 mm in 19th week. Number of weeks under drought, surplus and normal conditions are shown in Table 1. It is clear from the Table 1 that the maximum number of drought weeks during the 15 years period was 15 was in the 19th week however, the minimum number of drought weeks i.e. 6 were found in the 33th and 35th standard week of the year.

The maximum number of Surplus weeks was 4 in the 27th, 32th and 34th week, while, the minimum numbers of surplus weeks i.e. 0 were found in the 6th and 19th standard week. The maximum number of normal weeks was 7 in the 33rd week while, the minimum numbers of normal weeks i.e. 0 were found in the 1st, 2nd, 3rd, 7th, 8th 9th, 10th, 11th, 14th, 16th, 17th, 18th, 19th, 21st, 43th, 45th, 46th, 47th, 48th, 49th, 50th and 52th standard week

Monthly rainfall

The average monthly rainfall of 15 years (2001-2015) is shown in Table 2 and graphically represented in figure 2. From the table it is clear that the average monthly rainfall of these periods was of erratic nature with minimum rainfall of 2.13 mm during November while the maximum rainfall of 161.38 mm during July was observed. The erratic distribution of precipitation was observed during Rabi season (October-January) thereby preventing the farmers to go for Rabi crops. Therefore, the irrigation must be assured for sowing of Rabi crops.

Estimation of weekly rainfall probabilities plays a significant role in crop planning.

Annual and seasonal rainfall

The annual and seasonal rainfall of 15 years (2001-2015) is shown in Table 3 and graphically represented in figure 3 and 4. It is clear from the table that annual rainfall of these periods was of erratic nature with minimum annual rainfall of 0 mm during 2013 while, the maximum annual rainfall was 760.1 mm during 2008. The maximum seasonal rainfall during monsoon season was 933.82 mm during 2003 while, minimum was 0 mm during 2013. As shown in Figure 3 the peak values of annual rainfall were observed during the year 2003, followed by 2008, 2010, 2011, 2015, 2001, 2009 and 2004 whereas droughts were observed during the year 2002 followed by 2012, 2005, 2006, 2007, 2014 and 2013 for which the annual rainfall was less than mean annual rainfall (498.77).

Table.1 Number of drought, normal and surplus weeks during 2001-2015

Standard Weeks	Average rainfall (mm)	Value of rainfall (mm)			Total number of weeks		
		Drought Week (less than)	Surplus week (more than)	Normal week (between)	Drought	Surplus	Normal
1	0.2	0.1	0.4	0.1-0.4	14	1	0
2	0.65	0.327	1.31	0.33-1.31	13	2	0
3	3.167	1.583	6.33	1.58-6.33	13	2	0
4	3.3	1.65	6.6	1.65-6.6	11	1	3
5	0.572	0.286	1.144	0.29-1.14	13	1	1
6	0.067	0.033	0.133	0.03-0.13	14	0	1
7	4.533	2.267	9.067	2.27-9.07	13	2	0
8	3.733	1.867	7.467	1.87-7.47	12	3	0
9	0.347	0.173	0.693	0.17-0.69	14	1	0
10	0.233	0.117	0.467	0.12-0.47	13	2	0
11	0.6	0.3	1.2	0.3-1.2	13	2	0
12	2.027	1.013	4.053	1.01-4.05	12	2	1
13	5	2.5	10	2.5-10	13	1	1
14	2.067	1.033	4.133	1.03-4.13	14	1	0
15	1.733	0.867	3.467	0.87-3.47	13	1	1
16	0.867	0.433	1.733	0.43-1.73	14	1	0
17	1.1	0.55	2.2	0.55-2.2	12	3	0
18	0.4	0.2	0.8	0.2-0.8	14	1	0
19	0	0	0	0-0	15	0	0
20	0.707	0.353	1.413	0.35-1.41	13	1	1
21	0.633	0.317	1.267	0.32-1.27	12	3	0
22	7.647	3.823	15.293	3.82-15.29	9	3	3
23	1.6	0.8	3.2	0.8-3.2	12	1	2
24	2.62	1.31	5.24	1.31-5.24	9	3	3
25	7.233	3.617	14.467	3.62-14.47	8	3	4

26	8.721	4.36	17.443	4.36-17.44	10	2	3
27	6.953	3.477	13.907	3.47-13.90	9	4	2
28	30.093	15.047	60.187	15.05-60.19	9	3	3
29	37.473	18.737	74.947	18.74-74.94	8	3	4
30	52.64	26.32	105.28	26.32-105.28	8	2	5
31	31.1	15.55	62.2	15.55-62.2	7	2	6
32	20.201	10.1006	40.403	10.10-40.40	8	4	3
33	36.14	18.07	72.28	18.07-72.28	6	2	7
34	29.207	14.603	58.413	14.60-58.41	7	4	4
35	28.073	14.037	56.147	14.04-56.14	6	2	7
36	39.928	19.964	79.856	19.96-79.86	8	3	4
37	35.746	17.873	71.492	17.87-71.49	11	2	2
38	35.913	17.957	71.827	17.96-71.82	8	3	4
39	21.92	10.96	43.84	10.96-43.84	8	2	5
40	9.553	4.777	19.107	4.78-19.10	10	3	2
41	4.667	2.333	9.333	2.33-9.33	13	1	1
42	8.96	4.48	17.92	4.48-17.92	12	2	1
43	0.573	0.287	1.146667	0.29-1.14	14	1	0
44	1.6	0.8	3.2	0.8-3.2	12	2	1
45	0.267	0.133	0.533	0.13-0.53	14	1	0
46	0.6	0.3	1.2	0.3-1.2	14	1	0
47	0.533	0.267	1.067	0.27-1.07	14	1	0
48	0.8	0.4	1.6	0.4-1.6	14	1	0
49	0.533	0.267	1.067	0.27-1.07	14	1	0
50	0.067	0.033	0.133	0.03-0.13	14	1	0
51	2.96	1.48	5.92	1.486.6-5.92	12	1	2
52	**0.653**	**0.327**	**1.307**	**0.33-1.31-1.30**	**12**	**3**	**0**

Table.2 Mean Monthly Rainfall during 2001-2015

Month	Monthly Rainfall (mm)
January	7.37
February	8.61
March	11.39
April	4.1
May	8.59
June	31.35
July	161.38
August	122.16
September	122.65
October	13.75
November	2.13
December	5.2

Table.3 Annual and seasonal rainfall distribution (2001-2015)

Year	Annual rainfall (mm)	Seasonal rainfall (June to Sep)	Seasonal rainfall/ Annual rainfall (%)
2001	562.18	474.38	84.38
2002	494.2	377.3	76.35
2003	975.2	933.82	95.76
2004	514.9	372.8	72.59
2005	392	374.5	95.53
2006	384.8	342.2	88.93
2007	280	194	69.29
2008	760.1	710.6	93.49
2009	532.6	442.8	83.14
2010	638.6	600.6	94.11
2011	636.3	631.1	99.18
2012	478.7	457.7	95.61
2013	0	0	0
2014	231.7	221.7	95.68
2015	600.7	429.8	71.56

Table.4 Probability and recurrence interval of annual rainfall (2001-2015)

Year	Annual Rainfall (mm)	Rainfall in decreasing order	Rank (m)	P=m/(N+1)	T=1/P	P (%) = m/(N+1)*100
2001	562.18	975.2	1	0.063	16	6.25
2002	494.2	760.1	2	0.125	8	12.5
2003	975.2	638.2	3	0.187	5.333	18.75
2004	514.9	636.3	4	0.25	4	25
2005	392	600.6	5	0.312	3.2	31.25
2006	384.8	562.18	6	0.375	2.667	37.5
2007	280	532.6	7	0.437	2.286	43.75
2008	760.1	514.9	8	0.5	2	50
2009	532.6	494.2	9	0.562	1.778	56.25
2010	638.2	478.7	10	0.625	1.6	62.5
2011	636.3	392	11	0.687	1.455	68.75
2012	478.7	384.8	12	0.75	1.333	75
2013	0	280	13	0.812	1.231	81.25
2014	231.7	231.7	14	0.875	1.143	87.5
2015	600.6	0	15	0.937	1.067	93.75

Table.5 Probability and recurrence interval of seasonal rainfall (2001-2015)

Year	Seasonal rainfall (June to September)	Rainfall in decreasing order	Rank (m)	P=m/(N+1)	T=1/P	P (%) = m/(N+1)*100
2001	474.38	933.82	1	0	0.063	474.38
2002	377.3	710.6	2	194	0.125	377.3
2003	933.82	631.1	3	221.7	0.188	933.82
2004	373.8	600.6	4	342.2	0.25	373.8
2005	374.5	474.38	5	373.8	0.313	374.5
2006	342.2	457.7	6	374.5	0.375	342.2
2007	194	442.8	7	377.3	0.438	194
2008	710.6	429.8	8	429.8	0.5	710.6
2009	442.8	377.3	9	442.8	0.563	442.8
2010	600.6	374.5	10	457.7	0.625	600.6
2011	631.1	373.8	11	474.38	0.687	631.1
2012	457.7	342.2	12	600.6	0.75	457.7
2013	0	221.7	13	631.1	0.813	0
2014	221.7	194	14	710.6	0.875	221.7
2015	429.8	0	15	933.82	0.937	429.8

Table.6 Expected monthly distribution of rainfall (mm) at different probability levels

Month	10%	30%	50%	70%	90%
Jan	24.81	12.99	5.52	0	0
Feb	30.59	15.7	6.27	0	0
Mar	49.38	23.65	7.35	0	0
April	12.66	6.86	3.19	0.086	0
May	26.86	14.48	6.64	0.015	0
June	76.89	46.04	26.51	9.99	0
July	313.89	210.57	145.14	89.85	39.73
Aug	208.75	150	112.79	81.35	52.86
Sep	331.49	190.02	100.42	24.69	0
Oct	46.21	24.22	10.29	0	0
Nov	9.19	4.41	1.38	0	0
Dec	18.89	9.87	4.15	0	0
Total	1149.61	708.81	429.65	205.98	92.59

Table.7 Expected weekly distribution of rainfall (mm) at different probability levels

Weeks	Rainfall (mm)				
	Probability Levels (%)				
	10%	30%	50%	70%	90%
1	1.21	0.52	0.093	0	0
2	3.16	1.46	0.39	0	0
3	14.39	6.79	1.97	0	0
4	17.98	8.03	1.74	0	0
5	3.12	1.39	0.3	0	0
6	0.4	0.17	0.031	0	0
7	21.17	9.9	2.76	0	0
8	14.71	7.27	2.56	0	0
9	2.09	0.91	0.16	0	0
10	1.04	0.49	0.15	0	0
11	2.99	1.37	0.34	0	0
12	8.81	4.21	1.3	0	0
13	26.85	12.05	2.67	0	0
14	12.48	5.42	0.96	0	0
15	9.45	4.22	0.91	0	0
16	5.23	2.27	0.4	0	0
17	4.53	2.2	0.74	0	0
18	2.41	1.05	0.19	0	0
19	0	0	0	0	0
20	3.92	1.74	0.36	0	0
21	2.51	1.24	0.43	0	0
22	24.21	12.99	5.89	0	0
23	8.28	3.76	0.89	0	0
24	8.87	4.64	1.95	0	0
25	21.68	11.89	5.69	0.46	0
26	28.11	14.97	6.66	0	0
27	20.48	11.32	5.51	0.61	0
28	78.08	45.57	24.98	7.59	0
29	96.71	56.58	31.17	9.69	0
30	149.85	83.99	42.29	7.04	0
31	75.87	45.54	26.33	10.09	0
32	48.09	29.19	17.23	7.12	0
33	85.68	52.12	30.87	12.9	0
34	67.69	41.62	25.11	11.15	0
35	77.63	44.06	22.79	4.83	0
36	111.01	62.86	32.36	6.59	0
37	111.65	60.23	27.66	0.14	0
38	110.32	59.91	27.99	1.013	0

39	71.199	37.81	16.67	0	0
40	31.59	16.66	7.21	0	0
41	25.79	11.48	2.41	0	0
42	38.08	18.35	5.86	0	0
43	3.46	1.5	0.27	0	0
44	6.89	3.31	1.037	0	0
45	1.61	0.69	0.12	0	0
46	3.62	1.57	0.28	0	0
47	3.22	1.39	0.25	0	0
48	4.83	2.09	0.37	0	0
49	3.22	1.39	0.24	0	0
50	0.4	0.17	0.03	0	0
51	15.34	6.95	1.64	0	0
52	2.76	1.33	0.43	0	0

Fig.1 Mean weekly rainfall distribution (2001-2015)

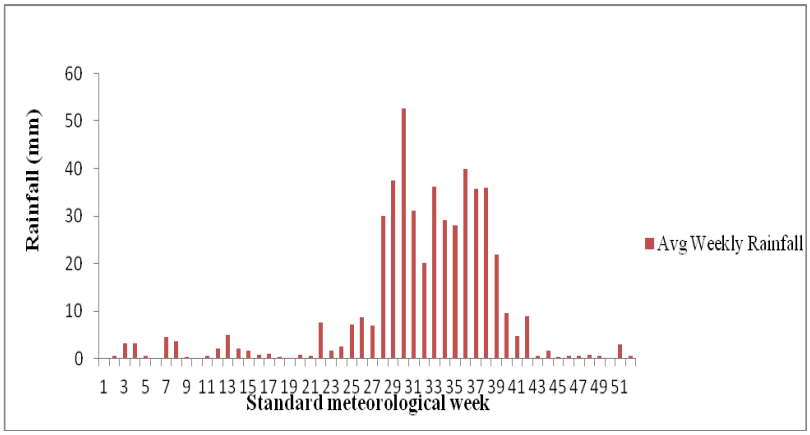


Fig.2 Mean monthly rainfall distribution (2001-2015)

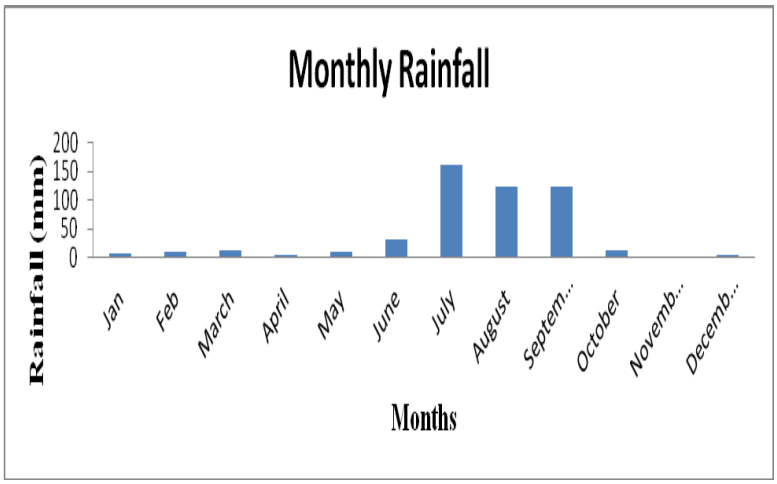


Fig.3 Annual rainfall distribution (2001-2015)

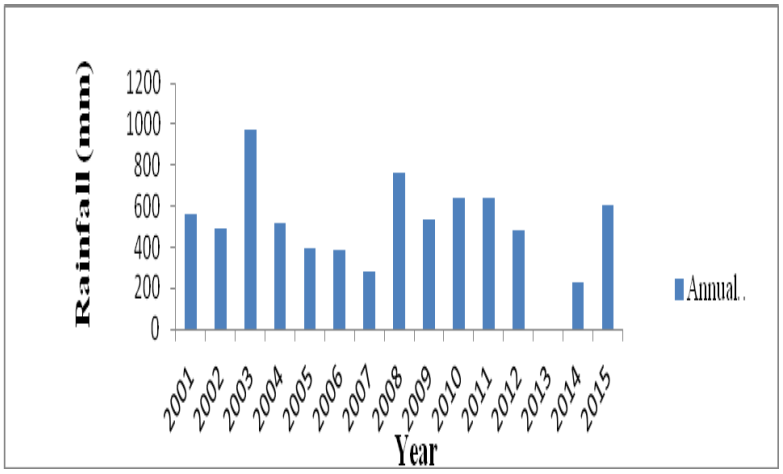


Fig.4 Seasonal rainfall distribution (2001-2015)

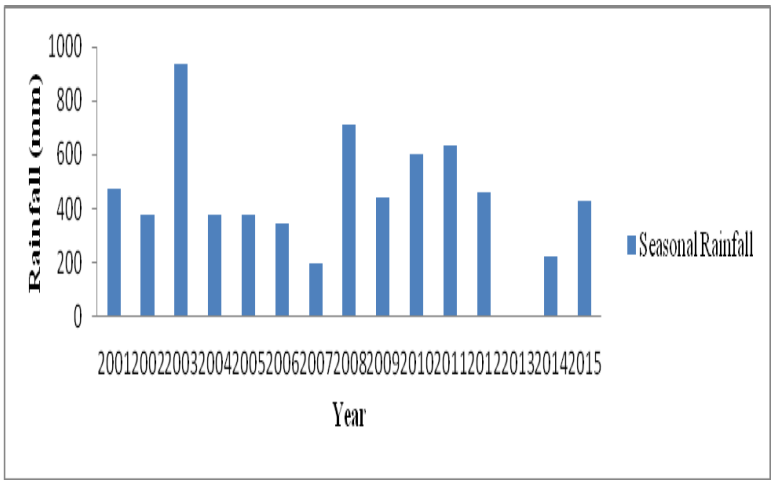


Fig.5 Recurrence interval of annual rainfall during (2001-2015)

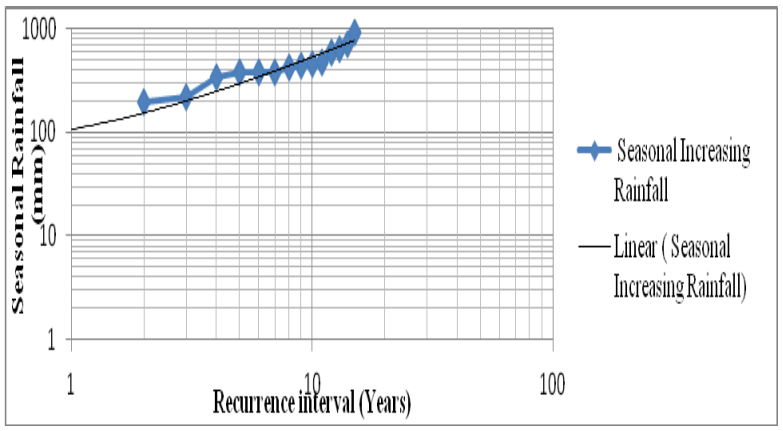
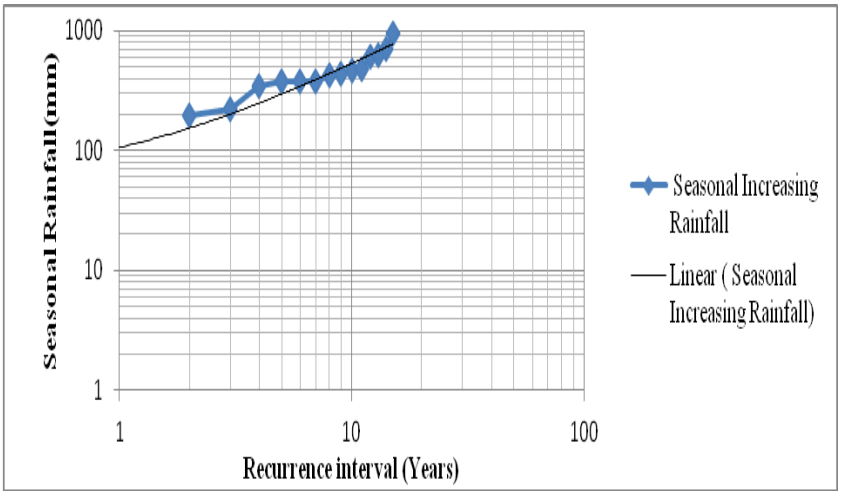


Fig.6 Recurrence interval of Seasonal rainfall during (2001-2015)



Probability analysis for annual rainfall and seasonal rainfall

The knowledge of annual rainfall and maximum daily rainfall is of great importance in hydrologic design of structures and flood control. To forecast the maximum daily rainfall, the probability curves were prepared for hydrological events. The observed maximum daily rainfall, annual rainfall and seasonal rainfall values with Weibull's probability distribution were plotted on the frequency curves. The rainfall values were decreasing with the increasing probability levels. The probabilities and recurrence interval of annual rainfall are shown in Table 4 and graphically represented in Figure 5 and probabilities and recurrence interval of seasonal rainfall are shown in Table 5 and graphically represented in Figure 6.

Analysis of Monthly Rainfall

The monthly rainfall at different probability level is given in Table 6. From the table it was clearly observed that at 10% probability level, the maximum rainfall was 331.49 mm during September while, the minimum rainfall was 9.19 mm during November. Also at 90% probability level, the maximum rainfall was 52.86 mm during July while, minimum rainfall of 0.00 mm was observed during January, February, March, April, May, June, September, October, November and December.

Analysis of Weekly Rainfall

The weekly rainfall at different probability level is given in Table 7. From the table it is clear that at 10% probability level, the maximum rainfall was observed 149.85 mm during 30^{th} week while, the minimum rainfall was observed 0 mm during 19^{th} week. The maximum rainfall at 30% probability level was 83.99 mm during 30^{th} week while, the minimum rainfall observed was 0 mm during 19^{th} week. Similarly, the maximum rainfall for 50% probability level was 42.29 mm during 30^{th} week while minimum rainfall was 0 mm during 19^{th} week. At 70% probability level maximum rainfall was 12.9 mm during 33^{th} week while, the minimum rainfall observed was 0 mm during 1^{st}-24^{th}, 26^{th} and 39^{th}-52^{nd} week.

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