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Investigating Drought Spells with Different Approaches for Nainital District of Uttarakhand

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Abstract- In this study, long-term daily rainfall dataset of Nainital district of Uttarakhand was analysed to study the occurrence of weekly and seasonal drought spells for better crop planning by employing criterion suggested by Ramdas and Mallik (1948) and Sharma *et al.* (1979). The intensity of drought spells calculated on weekly basis was compared with that obtained by methods suggested by Indian Meteorological Department, Pune (IMD method) and Ravikumar and Kaarmegam (revised IMD method). From analysis, it was found that the study area experienced about 50.67% drought weeks during *rabi* season and thereby, there is more than 50% chance of failure of crops under prevailing rainfall pattern. Keeping this in view, crops having lesser water requirement and/or of short-duration should be grown or advocated during *rabi* season. There is strong need to collect and utilize huge surplus surface runoff during *kharif* (rainy) season in water storage structures and recycling the same as life-saving irrigation will be useful for qualitative and quantitative production of commonly grown crops during *rabi* season in Nainital district.

Index Terms- Drought; weeks; season; IMD; revised IMD; crop planning.

1. INTRODUCTION

Rainfall is most important deciding factor for successful agriculture in hilly areas where only about 10% area is under irrigation and due to development of drought conditions owing to uneven, erratic and non-uniform distribution of rainfall, success of crop production always remain in question as it governs planning of crops and farm operations of an area, whereas, its distribution pattern and amount plays a very important role in deciding agricultural operations as availability of certain amount of rainfall at critical periods may lead to success or failure of various agricultural related issues. The fluctuation in monsoon alone attributes approximately 30 percent variation in grain production [1]. Excess rainfall may cause floods while its deficiency or uneven distribution may give rise to droughts which is the result of cumulative deficiency of rains for days, weeks, months and in some cases, years as well.

Various attempts have been made to define and classify drought but there is no universally acceptable definition of drought which varies according to the purpose and area of interest of investigator [2-3]. Drought is a climatic extreme which affects more people than any other form of natural disaster [4]. Among all natural disasters, droughts impact larger areas and causes significant losses in agricultural production [5]. Drought may occur in any part of the world, but its duration and intensity vary greatly across different climatic zones resulting in serious agricultural, environmental and socio-economic damages.

It is an established fact that coincidence of dry spells with sensitive phenological crop stages affect crop development adversely, whereas, occurrence of drought spells at ripening stage of crop sometimes has proved beneficial, therefore, it becomes imperative to study agricultural drought for crop planning on weekly basis to help farmers for getting better crop production. The analysis of rainfall and drought over a number of years could help in better crop planning so that production can be maximized with minimum losses. The variation in drought can be studied through statistical elements such as mean, standard deviation, coefficient of variation, percentage of average annual rainfall etc. [6]. The rainfall analysis on monthly, seasonal and annual basis may be misleading for deciding farm operation planning as a year generally considered as normal may have some abnormal and drought weeks as well [7].

The present study was being undertaken to evaluate occurrence of agricultural drought on weekly basis to suggest planning for crops to match uneven distribution and erratic nature of rainfall during different seasons. A number of investigators [8-21] studied rainfall variation to assess agricultural drought and plan crop related operations at different places.

2. MATERIALS AND METHODS

Daily rainfall dataset of 21 years (1992-2012) for Nainital district of Uttarakhand was used to evaluate variation in terms of statistical parameters by transforming daily data into standard meteorological weeks (SMWs) and seasons in standard CWS-1 format prescribed by Indian Meteorological Department (IMD), Pune. The drought investigations were determined by definitions proposed by [22-23] as:

- Normal week: any week receiving precipitation in between 50% and 200% of average weekly rainfall;
- Abnormal week: any week receiving precipitation more than twice of average weekly rainfall; and
- Drought week: any week receiving precipitation less than 50% of average weekly rainfall;

In the present study, IMD method (given by IMD, Pune) and revised IMD method [24] was utilized to understand intensity of weekly drought spells, described hereunder as:

IMD method: This method encompass drought assessment on the basis of percentage deviation of rainfall (D_i) from long-term average rainfall, expressed mathematically as, $D_i = 100*[(P_i\text{-}PM)/PM]$ where P_i is rainfall in time period "i" (week) and PM is long-term average rainfall. The percentage deviation of rainfall and categorization of drought assessment, prescribed by IMD as:

Percentage deviation (D_i)	Category
> 0	No drought
0 to -25	Mild
-25 to -50	Moderate
< -50	Severe

Revised IMD method: In this method, drought was assessed on the basis of percentage deviation of cumulative long-term average rainfall (CD_i), given by $CD_i = 100*[(PC_i\text{-}PCM_i)/PM]$ where PC_i and PCM_i are cumulative actual and cumulative long-term average rainfall up to time period "i" respectively, and PM is long-term average rainfall.

3. RESULTS AND DISCUSSIONS

The rainfall based criteria for D, A, and N SMWs and their distribution is presented in Table 1 and 2 respectively. From analysis, it is clear that during study period (1992-2012), 60.07%, 14.65% and 25.27% drought (D), abnormal (A) and normal (N) SMWs were observed. Thus, expected number of D, A, and N SMWs in a particular year will be 31.24, 7.62, and 13.14 respectively.

From Table 1 and 2, it is found that average weekly rainfall varied in the range of 1.45 mm (52 SMW) to 159.19 mm (33 SMW) and standard deviation (SD) and coefficient of variation (CV) varied in the range of 4.06-159.19 mm and 69.26-381.51% respectively. The average maximum rain of 183.60 mm was observed in 33 SMW. The number of weekly drought events varied in between a minimum of five (constituting to 0.76%) in both 28 and 30 SMW, and maximum of 19 (constituting to 2.90%) in 43 SMW during 21 years period of investigation. From Table 2, it is clear that 60.07% of total SMWs during study period were observed as drought. During monsoon season (24-40 SMWs), 22.10% drought SMWs were observed, whereas, during *kharif* (25-40 SMWs) and *rabi* (41-09 SMWs), 20.73% and 50.76% drought SMWs were occurred. This pattern of weekly drought occurrence during *rabi* season reveals that there is more than 50% chance of failure of *rabi* crops under prevailing rainfall pattern at Nainital district.

The drought intensity calculated with IMD and revised IMD method on weekly basis (Table 3) shows that on weekly basis, with IMD method, 59.98% severe, 8.06% moderate, 4.21% mild and 27.75% no drought weeks were observed. During *kharif* (25-40 SMW), 39.88%, 15.48%, 7.14%, and 37.50% weeks were observed as severe, moderate, mild and no-drought, whereas, in *rabi* (41-09 SMWs), these were found as 75.51%, 4.08%, 1.13% and 19.27% respectively. It was also found that 21.53% of total severe drought weeks occurred during 24-40 SMWs with maximum number (19 times) in 39 SMW.

With revised IMD method, 95.97% severe, 1.47% moderate, 0.55% mild and 2.01% no drought SMWs were observed during the period of investigation. During *kharif* season (25-40 SMW), 97.92%, 1.49%, 0.30%, and 0.30% weeks were respectively observed as severe, moderate, mild and no drought, whereas, in *rabi* season (41-09 SMWs), these were found as 91.84%, 2.49%, 0.91% and 4.76% respectively.

4. CONCLUSIONS

On the basis of foregoing, it can be concluded that during *rabi* season, 50.76% drought weeks were observed and this pattern reveals that there is more than 50% chance of failure of crops under prevailing rainfall pattern and, thereby, crops of short-duration and/or having lesser water requirement should be grown by collecting surplus surface runoff in water storage structures and recycling the same as life-saving irrigation for qualitative and quantitative production of different crops by ensuring availability of good soil moisture conditions in Nainital district.

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Table 1: Rainfall characteristics for drought (D), abnormal (A) and normal (N) weeks

SMW No.	Average rains (mm)	Percent of average annual rains (%)	CV (%)	SD (mm)	For drought SMW (mm)	For abnormal SMW (mm)	For normal SMW (mm)
1	5.75	0.27	179.53	10.32	< 2.87	≥ 11.49	2.87-11.49
2	2.93	0.14	187.30	5.49	< 1.46	≥ 5.86	1.46-5.86
3	7.19	0.34	270.30	19.43	< 3.59	≥ 14.38	3.59 -14.38
4	1.84	0.09	280.30	5.16	< 0.92	≥ 3.68	0.92 - 3.68
5	12.75	0.59	261.55	33.34	< 6.37	≥ 25.49	6.37 - 25.49
6	15.81	0.74	167.43	26.48	< 7.91	≥ 31.63	7.91 - 31.63
7	20.50	0.96	128.12	26.26	< 10.25	≥ 41.00	10.25 - 41.00
8	18.03	0.84	188.64	34.01	< 9.02	≥ 36.06	9.02 - 36.06
9	16.27	0.76	145.50	23.67	< 8.13	≥ 32.54	8.13 - 32.54
10	8.86	0.41	192.33	17.03	< 4.43	≥ 17.71	4.43 - 17.71
11	11.84	0.55	184.39	21.83	< 5.92	≥ 23.68	5.92 - 23.68
12	7.60	0.35	147.80	11.24	< 3.80	≥ 15.21	3.80 - 15.21
13	11.27	0.53	142.91	16.11	< 5.64	≥ 22.55	5.64 - 22.55
14	7.09	0.33	231.66	16.41	< 3.54	≥ 14.17	3.54 - 14.17
15	9.74	0.45	173.30	16.87	< 4.87	≥ 19.47	4.87 - 19.47
16	13.81	0.64	219.47	30.30	< 6.90	≥ 27.61	6.90 - 27.61
17	10.28	0.48	179.77	18.47	< 5.14	≥ 20.55	5.14 - 20.55
18	15.54	0.96	166.00	34.08	< 7.77	≥ 31.07	7.77 - 31.07
19	22.62	0.82	109.19	19.29	< 11.31	≥ 45.25	11.31 - 45.25
20	17.41	0.86	132.83	24.37	< 8.71	≥ 34.82	8.71 - 34.82
21	18.38	0.85	128.19	23.33	< 9.19	≥ 36.77	9.19 - 36.77
22	31.97	1.55	183.22	60.88	< 15.98	≥ 63.93	15.98 - 63.93
23	78.00	3.64	197.83	154.38	< 39.00	≥ 156.00	39.00 - 156.00
24	64.62	3.04	92.74	60.37	< 32.31	≥ 129.25	32.31 - 129.25
25	77.43	3.75	72.85	58.61	< 38.72	≥ 154.86	38.72 - 154.86
26	119.83	5.33	81.28	92.87	< 59.91	≥ 239.66	59.91 - 239.66
27	115.43	5.39	97.40	112.43	< 57.71	≥ 230.86	57.71 - 230.86
28	141.38	6.60	82.88	117.17	< 70.69	≥ 282.77	70.69 - 282.77
29	143.48	6.69	78.63	112.81	< 71.74	≥ 286.95	71.74 - 286.95
30	110.01	5.13	69.26	76.19	< 55.01	≥ 220.02	55.01 - 220.02
31	123.98	5.78	72.50	89.89	< 61.99	≥ 247.96	61.99 - 247.96
32	110.55	5.16	107.92	119.31	< 55.28	≥ 221.10	55.28 - 221.10
33	183.60	8.57	86.71	159.19	< 91.80	≥ 367.20	91.80 - 367.20
34	121.22	5.66	79.71	96.63	< 60.61	≥ 242.45	60.61 - 242.45
35	86.35	4.03	95.27	82.27	< 43.18	≥ 172.71	43.18 - 172.71
36	120.17	5.61	101.56	122.05	< 60.08	≥ 240.34	60.08 - 240.34
37	78.40	3.66	82.87	64.97	< 39.20	≥ 156.80	39.20 - 156.80
38	93.15	4.35	132.82	123.73	< 46.58	≥ 186.30	46.58 - 186.30
39	58.35	2.72	201.67	117.67	< 29.17	≥ 116.69	29.17 - 116.69
40	26.55	1.24	197.58	52.47	< 13.28	≥ 53.11	13.28 - 53.11
41	9.53	0.44	294.40	28.04	< 4.76	≥ 19.05	4.76 - 19.05
42	19.09	0.89	375.26	71.63	< 9.54	≥ 38.17	9.54 - 38.17
43	2.49	0.12	338.32	8.41	< 1.24	≥ 4.97	1.24 - 4.97
44	2.43	0.11	295.69	7.19	< 1.22	≥ 4.86	1.22 - 4.86
45	3.05	0.14	244.84	7.46	< 1.52	≥ 6.10	1.52 - 6.10
46	2.45	0.11	323.95	7.94	< 1.23	≥ 4.90	1.23 - 4.90
47	2.01	0.09	232.62	4.68	< 1.01	≥ 4.02	1.01 - 4.02
48	3.45	0.16	284.63	9.82	< 1.72	≥ 6.90	1.72 - 6.90
49	1.55	0.07	261.78	4.06	< 0.78	≥ 3.10	0.78 - 3.10
50	4.34	0.20	272.76	11.84	< 2.17	≥ 8.68	2.17 - 8.68
51	1.91	0.09	381.51	7.29	< 0.96	≥ 3.82	0.96 - 3.82
52	1.45	0.07	287.85	4.17	< 0.72	≥ 2.90	0.72 - 2.90

CV = coefficient of variation, SD = standard deviation.

Table 2: Distribution of drought (D), abnormal (A) and normal (N) weeks

SMW No.	Number of weeks			Percentage of weeks falling in given total weeks (%) as			Percentage of total years having given weeks (%) as		
	D	A	N	D	A	N	D	A	N
1	15	2	4	0.72	2.29	2.50	71.43	19.05	9.52
2	15	1	5	0.36	2.29	3.13	71.43	23.81	4.76
3	16	3	2	1.09	2.44	1.25	76.19	9.52	14.29
4	17	1	3	0.36	2.59	1.88	80.95	14.29	4.76
5	15	4	2	1.45	2.29	1.25	71.43	9.52	19.05
6	12	5	4	1.81	1.83	2.50	57.14	19.05	23.81
7	11	5	5	1.81	1.68	3.13	52.38	23.81	23.81
8	14	4	3	1.45	2.13	1.88	66.67	14.29	19.05
9	13	2	6	0.72	1.98	3.75	61.90	28.57	9.52
10	15	2	4	0.72	2.29	2.50	71.43	19.05	9.52
11	13	5	3	1.81	1.98	1.88	61.90	14.29	23.81
12	13	4	4	1.45	1.98	2.50	61.90	19.05	19.05
13	11	6	4	2.17	1.68	2.50	52.38	19.05	28.57
14	16	2	3	0.72	2.44	1.88	76.19	14.29	9.52
15	13	4	4	1.45	1.98	2.50	61.90	19.05	19.05
16	14	5	2	1.81	2.13	1.25	66.67	9.52	23.81
17	14	3	4	1.09	2.13	2.50	66.67	19.05	14.29
18	14	3	4	1.09	2.13	2.50	66.67	19.05	14.29
19	10	8	3	2.90	1.52	1.88	47.62	14.29	38.10
20	11	6	4	2.17	1.68	2.50	52.38	19.05	28.57
21	11	7	3	2.54	1.68	1.88	52.38	14.29	33.33
22	12	7	2	2.54	1.83	1.25	57.14	9.52	33.33
23	11	9	1	3.26	1.68	0.63	52.38	4.76	42.86
24	9	9	3	3.26	1.37	1.88	42.86	14.29	42.86
25	7	11	3	3.99	1.07	1.88	33.33	14.29	52.38
26	9	9	3	3.26	1.37	1.88	42.86	14.29	42.86
27	9	10	2	3.62	1.37	1.25	42.86	9.52	47.62
28	5	14	2	5.07	0.76	1.25	23.81	9.52	66.67
29	6	12	3	4.35	0.91	1.88	28.57	14.29	57.14
30	5	15	1	5.43	0.76	0.63	23.81	4.76	71.43
31	6	13	2	4.71	0.91	1.25	28.57	9.52	61.90
32	10	8	3	2.90	1.52	1.88	47.62	14.29	38.10
33	7	11	3	3.99	1.07	1.88	33.33	14.29	52.38
34	8	10	3	3.62	1.22	1.88	38.10	14.29	47.62
35	8	9	4	3.26	1.22	2.50	38.10	19.05	42.86
36	9	8	4	2.90	1.37	2.50	42.86	19.05	38.10
37	6	13	2	4.71	0.91	1.25	28.57	9.52	61.90
38	11	5	5	1.81	1.68	3.13	52.38	23.81	23.81
39	16	1	4	0.36	2.44	2.50	76.19	19.05	4.76
40	14	3	4	1.09	2.13	2.50	66.67	19.05	14.29
41	16	3	2	1.09	2.44	1.25	76.19	9.52	14.29
42	17	3	1	1.09	2.59	0.63	80.95	4.76	14.29
43	19	0	2	0.00	2.90	1.25	90.48	9.52	0.00
44	17	1	3	0.36	2.59	1.88	80.95	14.29	4.76
45	17	1	3	0.36	2.59	1.88	80.95	14.29	4.76
46	18	1	2	0.36	2.74	1.25	85.71	9.52	4.76
47	17	0	4	0.00	2.59	2.50	80.95	19.05	0.00
48	17	1	3	0.36	2.59	1.88	80.95	14.29	4.76
49	17	0	4	0.00	2.59	2.50	80.95	19.05	0.00
50	15	3	3	1.09	2.29	1.88	71.43	14.29	14.29
51	18	2	1	0.72	2.74	0.63	85.71	4.76	9.52
52	17	2	2	0.72	2.59	1.25	80.95	9.52	9.52

Table 3: Weekly drought intensity by IMD and revised IMD methods

SMW	IMD method				Revised IMD method			
No.	S	Mod	Mi	ND	S	Mod	Mi	ND
1	2.29	1.14	0.00	1.65	1.43	6.25	0.00	22.73
2	2.29	1.14	0.00	1.65	1.53	0.00	16.67	18.18
3	2.44	1.14	0.00	1.32	1.62	6.25	16.67	9.09
4	2.60	1.14	0.00	0.99	1.81	6.25	0.00	4.55
5	2.29	1.14	4.35	0.99	1.72	6.25	0.00	9.09
6	1.83	3.41	2.17	1.65	1.53	12.50	0.00	13.64
7	1.68	2.27	0.00	2.64	1.53	6.25	33.33	9.09
8	2.14	2.27	0.00	1.65	1.72	6.25	0.00	9.09
9	1.98	1.14	2.17	1.98	1.72	18.75	0.00	0.00
10	2.29	0.00	2.17	1.65	2.00	0.00	0.00	0.00
11	1.98	1.14	0.00	2.31	1.91	0.00	16.67	0.00
12	1.98	0.00	2.17	2.31	2.00	0.00	0.00	0.00
13	1.68	2.27	2.17	2.31	2.00	0.00	0.00	0.00
14	2.44	0.00	2.17	1.32	2.00	0.00	0.00	0.00
15	1.98	1.14	0.00	2.31	2.00	0.00	0.00	0.00
16	2.14	2.27	0.00	1.65	1.91	6.25	0.00	0.00
17	2.14	1.14	2.17	1.65	2.00	0.00	0.00	0.00
18	2.29	0.00	0.00	1.98	1.91	6.25	0.00	0.00
19	1.53	0.00	6.52	2.64	2.00	0.00	0.00	0.00
20	1.83	1.14	2.17	2.31	2.00	0.00	0.00	0.00
21	1.83	3.41	0.00	1.98	2.00	0.00	0.00	0.00
22	1.83	2.27	2.17	1.98	1.91	0.00	16.67	0.00
23	1.68	2.27	4.35	1.98	1.91	0.00	0.00	4.55
24	1.07	3.41	10.87	1.98	1.91	6.25	0.00	0.00
25	0.92	3.41	4.35	3.30	2.00	0.00	0.00	0.00
26	1.22	3.41	2.17	2.97	2.00	0.00	0.00	0.00
27	1.37	2.27	2.17	2.97	1.91	6.25	0.00	0.00
28	0.76	4.55	10.87	2.31	1.91	6.25	0.00	0.00
29	0.92	4.55	4.35	2.97	2.00	0.00	0.00	0.00
30	0.76	6.82	0.00	3.30	2.00	0.00	0.00	0.00
31	0.92	4.55	6.52	2.64	2.00	0.00	0.00	0.00
32	1.53	1.14	4.35	2.64	2.00	0.00	0.00	0.00
33	1.07	4.55	4.35	2.64	2.00	0.00	0.00	0.00
34	1.22	3.41	2.17	2.97	2.00	0.00	0.00	0.00
35	1.22	5.68	0.00	2.64	2.00	0.00	0.00	0.00
36	1.37	4.55	2.17	2.31	2.00	0.00	0.00	0.00
37	0.92	6.82	2.17	2.64	2.00	0.00	0.00	0.00
38	1.68	2.27	4.35	1.98	2.00	0.00	0.00	0.00
39	2.44	1.14	0.00	1.32	2.00	0.00	0.00	0.00
40	2.14	0.00	2.17	1.98	2.00	0.00	0.00	0.00
41	2.44	1.14	0.00	1.32	2.00	0.00	0.00	0.00
42	2.60	1.14	0.00	0.99	2.00	0.00	0.00	0.00
43	2.90	0.00	0.00	0.66	2.00	0.00	0.00	0.00
44	2.60	1.14	0.00	0.99	2.00	0.00	0.00	0.00
45	2.60	1.14	0.00	0.99	2.00	0.00	0.00	0.00
46	2.75	0.00	0.00	0.99	2.00	0.00	0.00	0.00
47	2.60	0.00	0.00	1.32	2.00	0.00	0.00	0.00
48	2.60	0.00	0.00	1.32	2.00	0.00	0.00	0.00
49	2.60	0.00	0.00	1.32	2.00	0.00	0.00	0.00
50	2.29	1.14	2.17	1.32	2.00	0.00	0.00	0.00
51	2.75	0.00	0.00	0.99	2.00	0.00	0.00	0.00
52	2.60	0.00	0.00	1.32	2.00	0.00	0.00	0.00

S = severe, Mod = moderate, Mi = Mild, and ND = no drought.