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Research Article

Assured Rainfall and Dry Spell Analysis for Crop Planning in East Champaran District of Bihar

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ABSTRACT

Soil moisture is the major limiting factor for crop production under rainfed condition. Therefore, agricultural planning needs to be prepared based on climatic potential of the area. For this, minimum assured weekly rainfall at 10, 25, 50, 75 and 90% probability levels were computed over East Champaran district by using historical weekly rainfall data of Chakia, Mehasi and Motihari rain-gauge stations for a period of 48 years (1965-2012). Initial and conditional probabilities of weekly rainfall and dry spell sequences during summer, *kharif* and *rabi* seasons were worked out for efficient crop planning. Considering 20 mm weekly rainfall, moisture sufficiency period prevailed at 25-35 SMW (Standard meteorological week) at 75% probability level. When weekly water requirement of rice (without water stress) of 50 mm was considered, the stable rainfall period continued for 9 weeks (26-34 SMW) at 50% probability. The probability of dry spell increased significantly after 38 SMW in the district.

Key words: Assured rainfall, Conditional probability, Dry spell, Crop planning

Introduction

Rainfall is the single most important factor which controls crop production under rainfed condition, where almost all agricultural operations are dependent upon the probability of receiving certain amount of rainfall. As compared to other weather elements, the amount and distribution of rainfall in a given location vary greatly. Comprehensive idea on probability of a certain amount of rainfall during a certain period is essential in view of its economic implications of weather sensitive operations for production (Virmani *et al.,* 1982). Water stress for a few days during sensitive growth stages could be disastrous for crop production. A number of risks are involved in rainfed crop production due to uncertainty in rainfall and occurrence of droughts (Misra, 2005). In rainfed areas, rainfall is the only water resource and therefore, the crop planning must be based on potentially high rain water utilization technology. A better understanding of rainfall pattern through rainfall probability analysis should work for sound and efficient cropping systems (Singandhupe *et al.*, 2000). Many workers emphasized the utility of crop plan based on rainfall amount estimated at different probability levels (Sarker *et al*, 1982; Deka and Nath, 2000; Manikandan *et al*., 2014). Hence, studies involving estimation of assured rainfall week-by-week will provide information useful for evaluating climatic potential for agricultural

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development and evolving suitable cropping patterns (Sarker *et al.*, 1982).

East Champaran district is located in north-west alluvial plain zone (Zone I) of Bihar. The area comes under dry sub-humid climate. This paper discusses on computation of assured weekly rainfall and dry spell sequences at different probability levels for enhancing and stabilizing rainfed crop production through rational crop planning in East Champaran district.

Materials and Methods

Weekly rainfall data for the period of 48 years (1965-2012) pertaining to three locations *viz.* Chakia, Mehasi and Motihari were used for district level rainfall analysis. The assured rainfall amount at 10, 25, 50, 75 and 90% probability levels were computed through incomplete gamma distribution technique developed by Thom (1958) and described by Sarker and Biswas (1986 & 1988). The weekly assured rainfall estimated at different probability levels constitutes a series of data that may be expected in different years. Hence, risk involved in getting a certain amount of rainfall during a particular period may be obtained from this analysis.

The equations (Sarker and Biswas, 1986 & 1988) used for computation of minimum assured rainfall are Gamma distribution:

G(X)= q+ pF(X)
F(X)= Gamma distribution function
q= probability of zero precipitation and p=1-q.

$$F(X) = \int_0^x \frac{x^{\gamma-1} e^{(-\frac{x}{\beta})}}{(\beta)^{\gamma}\,\tau\gamma} dx$$

X, γ, β >0
F(X)=0, when X ≤ 0
Where γ, β are the shape and scale parameters respectively.
τ_γ is the gamma function

H(X)= Probability of rain ≤ X

The probability of rain < X, $H(X) = [Q + (1-Q)] = \int_0^x \frac{x^{\gamma-1} e^{(-\frac{x}{\beta})}}{(\beta)^{\gamma}\,\tau\gamma} dx$, Q is the empirical probability of zero rain, being the ratio of occasions of zero rain to the total number of occasions and X includes zero rain also.

The probability of rain ≥ X,

$$P_x = 1 - H(X) = (1-Q) = \left\{ \int_0^x \frac{x^{\gamma-1} e^{(-\frac{x}{\beta})}}{(\beta)^{\gamma}\,\tau\gamma} dx \right\}$$

Rainfall at probability levels can be estimated by iteration process, and termed as assured rainfall with respective probability. Using software based on these methodologies, the amount of assured rainfall at different probability level was computed.

Probabilities of 2 and 3 consecutive dry weeks with threshed rainfall amount of 10 mm per week were worked out for the district following Olderman and Frere (1982). Initial and conditional probabilities of getting weekly threshold rainfall (10, 20, 30 and 50 mm per week) were computed as suggested by Robertson (1976) and adopted by Virmani *et al.* (1982) and Samui *et al.* (2013). With this analysis, initial and conditional probabilities were obtained.

Initial probability

P (D) = Probability of dry week,

P (W) = Probability of wet week,

Conditional probability

P (W/W) = Probability of a wet week followed by a wet week

P (D/D) = Probability of a dry week followed by a dry week

P (D/W) = Probability of a dry week followed by a wet week

P (W/D) = Probability of a wet week followed by a dry week

Results and Discussion

Assured weekly rainfall probability

At 50% probability level, weekly threshold rainfall of 20 mm was available during 23 to 40 standard meteorological weeks (SMW) (Table 1).

Table 1. Assured weekly rainfall (mm) at probability levels in East Champaran district (data base: 1965-2012)

SMW	Date	Assured weekly rainfall (mm) at probability of					Mean weekly rainfall (mm)
		90%	75%	50%	25%	10%	
1	1 – 7 Jan	0.3	0.8	2.1	4.5	7.8	2.3
2	8 – 14 Jan	0.3	0.8	1.9	3.8	6.3	1.7
3	15 – 21 Jan	0.3	0.9	2.7	6.1	11	3.5
4	22– 28 Jan	0.3	1.0	2.8	6.3	11.2	3.6
5	29 Jan – 4 Feb	0.3	1.0	2.9	6.4	11.4	3.6
6	5 – 11 Feb	0	0.0	2.7	8.1	12	2.7
7	12 – 18 Feb	0	0.1	3.7	9.3	13.4	3.7
8	19 – 25 Feb	0	0	3.5	10.1	15.1	3.5
9	26 Feb – 4 Mar	0.3	0.8	1.8	3.5	5.7	1.5
10	5 – 11 Mar	0.5	0.9	1.5	2.4	3.4	0.8
11	12 – 18 Mar	0.3	0.8	2	3.9	6.4	1.8
12	19 – 25 Mar	0.3	0.9	2.3	4.7	7.9	2.4
13	26 Mar – 1 Apr	0.3	0.9	2.4	5	8.6	2.6
14	2 – 8 Apr	0.5	0.9	1.8	3.2	4.9	1.3
15	9 – 15 Apr	0.2	0.8	2.4	5.6	10.2	3.1
16	16 – 22 Apr	0.2	0.9	4	11.4	23.2	7.6
17	23 – 29 Apr	0.4	1.4	4.2	9.6	17.2	6.0
18	30 Apr – 6 May	0.5	1.9	6.3	15.4	28.5	10.2
19	7 – 13 May	0.6	2.3	6.8	15.7	28.4	10.4
20	14 – 20 May	0.6	2.6	8.6	21.1	39.5	14.5
21	21 – 27 May	0.9	3.6	11.9	29.1	54.1	20.3
22	28 May – 3 Jun	0.9	3.7	11.9	28.6	52.8	19.9
23	4 – 10 Jun	2	7.2	21.4	49	87.9	34.5
24	11 – 17 Jun	3.1	9.5	25	52.9	90.9	37.2
25	18 – 24 Jun	7.6	19.9	42.1	80.2	129.3	56.9
26	25 Jun – 1 Jul	10.9	25.8	56	104.3	166.1	74.5
27	2 – 8 Jul	11.8	28.7	63.4	119.8	192.2	85.6
28	9 – 15 Jul	13.9	30.4	62	111	172.2	79.7
29	16 – 22 Jul	20	40.3	76.9	131.6	198.3	95.4
30	23 – 29 Jul	12.9	29.4	61.6	112.4	176.5	80.5
31	30 Jul – 5 Aug	9.6	23.1	50.4	94.5	151	67.4
32	6 – 12 Aug	9.9	22.1	45.7	82.7	129.1	59.0
33	13 – 19 Aug	10.1	27.3	65.5	130.4	216.1	93.1
34	20 – 26 Aug	12.6	29	61.3	112.3	177	80.4
35	27 – 2 Sep	11.6	23	43.5	73.8	110.6	53.1
36	3 – 9 Sep	4	12.8	34.5	74.3	128.8	52.7
37	10 – 16 Sep	8.5	20	43.2	80.3	127.7	57.2
38	17 – 23 Sep	2	8	25.5	60.9	112.1	43.4
39	24 – 30 Sep	1.7	8	28.4	72.1	137.1	52.1
40	1 – 7 Oct	0.9	5.3	21.6	59.5	118.3	43.5
41	8 – 14 Oct	0.6	2.5	7.9	18.5	33.8	12.5
42	15 – 21 Oct	0.2	1.4	6.1	17.5	35.6	12.2
43	22 – 28 Oct	0.2	0.8	2	4.2	7.2	2.0
44	29 Oct – 4 Nov	0.4	0.8	1.4	2.4	3.7	0.8
45	5 – 11 Nov	0.2	0.7	2.3	5.8	10.9	3.3
46	12 – 18 Nov	0.4	0.8	1.3	2.1	3	0.6
47	19 – 25 Nov	0.4	0.7	1.2	1.8	2.6	0.4
48	26 Nov – 2 Dec	0.4	0.7	1.2	2	2.9	0.5
49	3 – 9 Dec	0.4	0.7	1.2	2	2.8	0.5
50	10 – 16 Dec	0.2	0.7	1.6	3.3	5.5	1.4
51	17 – 23 Dec	0.3	0.7	1.3	2.2	3.4	0.6
52	24 – 31 Dec	0.2	0.8	2.6	6.2	11.4	3.5
Annual		929.2	1090.1	1287.2	1508.2	1727.3	1311.2

SMW: Standard meteorological week

The rainfall amount of 20 mm per week was found to provide enough moisture for sowing of upland crops and therefore, 20 mm rainfall per week in the beginning of the season was considered optimum (Ramana Rao *et al*., 1983). Since this amount of rainfall was fairly adequate at all growth stages of rainfed upland crops (Subramaniam and Rao, 1989), number of weeks with assured rainfall ≥ 20 mm could be the length of cropping period. Accordingly, period for rainfed cropping in East Champaran district was estimated at 18 weeks. At this probability (50%) level, sowing of rainfed crops could be planned during 23 SMW. However at higher probability (75%) level, with lesser operating risks, rainfed crop growing period ranges from 25 to 35 SMW with sowing week starting at 25 SMW. Total annual rainfall at 50 and 75% probability levels were 1287.2 and 1090.1 mm, respectively. The earliest sowing of rainfed crops with 20 mm weekly rainfall at 10% probability (one in 10 yrs) could be set at 16 SMW. Period with 20 mm weekly rainfall at 75% probability is the core rainfall period, during which drought hazard remains low and thus, this could be regarded as moisture sufficiency period (Sarkar, 1994). Emphasis should be given on those crops/crop varieties whose growing cycle is completed within the period matching with water availability period as identified.

Initial and conditional probabilities of rainfall

Initial and conditional probabilities of receiving 10, 20, 30 and 50 mm rainfall per week during summer, *kharif* and *rabi* seasons for the district are presented in Table 2. Various degrees of wetness with different thresholds of rainfall represent approximately 0.15 to ≤ 1.0 of potential evapotranspiration for different seasons and crop phenophases (Virmani *et al.*, 1982). The soil of the district is predominantly medium textured. At least 20 mm rainfall is required for land preparation and sowing work. An initial probability of receiving 20 mm rainfall per week (PW) exceeded 50% during the period from 23 to 39 SMW, while during 25-35 SMW, the probability was ≥ 75%. The results at higher probability level implied that if a farmer intends to operate at lower risk level (*e.g.* 75% probability), he has to choose crops and cropping pattern in such a way that the durations of crops is 3-4 weeks less than those operating at higher risk level (*e*.g. 50% probability). In such situations, the sowing schedules need to be adjusted in such a way that critical phases of crop growth could occur during the weeks with maximum probability of having 20 mm rainfall (Subramaniam and Rao, 1989).

The P(W/W) with 20 mm rainfall at ≥50% probability in the district started at 23 SMW and ended at 39 SMW. Considering the evapotranspiration and percolation losses from rice fields of 3 and 4 mm d^{-1} , respectively in eastern India, water requirement of rice without stress could be taken as 50 mm in a week (Singh and Singh, 2000). Chaudhary and Tomar (1999) and Dey *et al.* (2011) considered this amount as a stable rainfall for rice. Based on this, the growing period of rainfed rice in the district was estimated at 9 weeks (26-34 SMW at 50% probability). Considering 20-25 days for seeding and 25-30 days for maturity stage of short to medium duration rice (*Prabhat, Dhanlaxmi, Richhariya, Turanta, Santosh etc*) with 90-120 days to maturity could be recommended for the district. While considering P(W/D), periods of 28-29, 31 and 33-35 SMW showed probability >7% (Fig. 1).

Dry spell probability

Probability of occurrence of dry spell of consecutive two and three weeks remains very low (<10%) during major part of *kharif* crop growing season (Fig. 2). However, chances of getting dry spell of consecutive two and three weeks are high during summer and *rabi* seasons. The probabilities of dry spell of consecutive two and three weeks increases significantly after 38 SMW. Thus, chances of crops experiencing moisture stress are very high after 38 SMW. Dry spell coinciding with sensitive phases can adversely affect the growth and yield of crop. To the contrary, the wet spell during certain phases of growth is beneficial.

Table 2. Initial and conditional probabilities of weekly rainfall in East Champaran district (data base: 1965-2012)

SMW	10 mm			20 mm			30 mm			50 mm			Mean RF*
	W	W/W	W/D	W	W/W	W/D	W	W/W	W/D	W	W/W	W/D	(mm)
Summer/*Zaid* season													
11	0.06	0	0.06	0.02	0	0.02	0	0	0	0	0	0	1.8
12	0.10	0	0.11	0.02	0	0.02	0.02	0	0.02	0	0	0	2.4
13	0.10	0.40	0.07	0.02	0	0.02	0	0	0	0	0	0	2.6
14	0.02	0	0.02	0	0	0	0	0	0	0	0	0	1.3
15	0.06	0	0.06	0.02	0	0.02	0.02	0	0.02	0.02	0	0.02	3.1
16	0.21	0.67	0.18	0.15	0	0.15	0.06	0	0.06	0.06	0	0.06	7.6
17	0.23	0.30	0.21	0.08	0	0.10	0.06	0	0.07	0	0	0	6.0
18	0.27	0.45	0.22	0.19	0.50	0.16	0.13	0	0.13	0.02	0	0.02	10.2
19	0.35	0.54	0.29	0.21	0.22	0.21	0.10	0	0.12	0.02	0	0.02	10.4
20	0.46	0.41	0.48	0.27	0.30	0.26	0.19	0	0.21	0.06	0	0.06	14.5
21	0.54	0.68	0.42	0.40	0.54	0.34	0.23	0.44	0.18	0.10	0.33	0.09	20.3
22	0.52	0.54	0.50	0.38	0.32	0.41	0.25	0.27	0.24	0.04	0.20	0.02	19.9
23	0.67	0.80	0.52	0.52	0.78	0.37	0.44	0.58	0.39	0.27	1.00	0.24	34.5
***Kharif* season**													
24	0.71	0.69	0.75	0.56	0.64	0.48	0.48	0.62	0.37	0.31	0.38	0.29	37.2
25	0.88	0.85	0.93	0.77	0.74	0.81	0.67	0.74	0.60	0.46	0.53	0.42	56.9
26	0.85	0.83	1.00	0.81	0.81	0.82	0.71	0.72	0.69	0.58	0.55	0.62	74.5
27	0.92	0.93	0.86	0.90	0.90	0.89	0.77	0.79	0.71	0.54	0.54	0.55	85.6
28	0.88	0.86	1.00	0.83	0.81	1.00	0.81	0.76	1.00	0.60	0.58	0.64	79.7
29	0.96	1.00	0.67	0.88	0.90	0.75	0.83	0.87	0.67	0.75	0.79	0.68	95.4
30	0.98	0.98	1.00	0.81	0.88	0.33	0.67	0.75	0.25	0.56	0.64	0.33	80.5
31	0.90	0.89	1.00	0.83	0.85	0.78	0.73	0.78	0.63	0.52	0.59	0.43	67.4
32	0.88	0.88	0.80	0.75	0.80	0.50	0.71	0.74	0.62	0.52	0.56	0.48	59.0
33	0.88	0.88	0.83	0.85	0.89	0.75	0.75	0.76	0.71	0.63	0.76	0.48	93.1
34	0.92	0.90	1.00	0.81	0.80	0.86	0.73	0.67	0.92	0.58	0.53	0.67	80.4
35	0.92	0.91	1.00	0.81	0.77	1.00	0.65	0.57	0.85	0.40	0.36	0.45	53.1
36	0.83	0.89	0.25	0.67	0.74	0.33	0.54	0.61	0.41	0.27	0.32	0.24	52.7
37	0.88	0.90	0.75	0.67	0.66	0.69	0.63	0.58	0.68	0.48	0.46	0.49	57.2
38	0.71	0.74	0.50	0.56	0.66	0.38	0.46	0.57	0.28	0.31	0.39	0.24	43.4
39	0.71	0.68	0.79	0.52	0.63	0.38	0.46	0.55	0.38	0.31	0.47	0.24	52.1
40	0.60	0.65	0.50	0.38	0.40	0.35	0.29	0.36	0.23	0.21	0.27	0.18	43.5
41	0.35	0.28	0.47	0.17	0.11	0.20	0.13	0	0.18	0.02	0	0.03	12.5
***Rabi* season**													
42	0.23	0.29	0.19	0.15	0.13	0.15	0.13	0.17	0.12	0.13	0	0.13	12.2
43	0.08	0.09	0.08	0.02	0	0.02	0.02	0	0.02	0	0	0	2.0
44	0.04	0	0.05	0	0	0	0	0	0	0	0	0	0.8
45	0.10	0	0.11	0.06	0	0.06	0.04	0	0.04	0.02	0	0.02	3.3
46	0.02	0.20	0	0	0	0	0	0	0	0	0	0	0.6
47	0.02	0	0.02	0	0	0	0	0	0	0	0	0	0.4
48	0.02	0	0.02	0	0	0	0	0	0	0	0	0	0.5
49	0.02	0	0.02	0	0	0	0	0	0	0	0	0	0.5
50	0.02	0	0.02	0.02	0	0.02	0.02	0	0.02	0	0	0	1.4
51	0.02	0	0.02	0.02	0	0.02	0	0	0	0	0	0	0.6
52	0.13	0	0.13	0.04	0	0.04	0.04	0	0.04	0.02	0	0.02	3.5
1	0.09	0.17	0.07	0.02	0.50	0	0.02	0.50	0	0	0	0	2.3
2	0.04	0	0.05	0.02	0	0.02	0.02	0	0.02	0	0	0	1.7
3	0.15	0	0.15	0.06	0	0.06	0.02	0	0.02	0	0	0	3.5
4	0.15	0.14	0.15	0.04	0	0.04	0.02	0	0.02	0	0	0	3.6
5	0.15	0.14	0.15	0.06	0	0.07	0	0	0	0	0	0	3.6
6	0.08	0.29	0.05	0.06	0.33	0.04	0	0	0	0	0	0	2.7
7	0.13	0	0.14	0.06	0	0.07	0	0	0	0	0	0	3.7
8	0.15	0	0.17	0.06	0	0.07	0.02	0	0.02	0	0	0	3.5
9	0.06	0.14	0.05	0.02	0	0.02	0	0	0	0	0	0	1.5
10	0	0	0	0	0	0	0	0	0	0	0	0	0.8

RF*- Rainfall

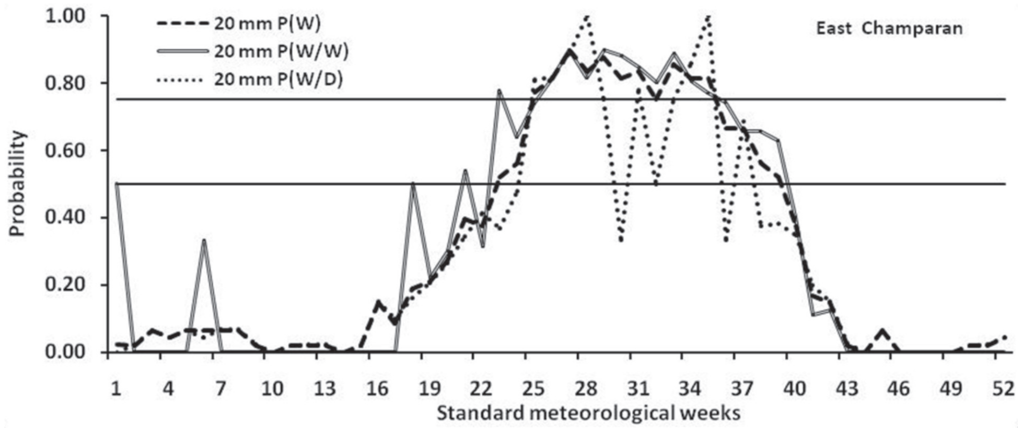

Fig.1. Initial and conditional probabilities of receiving weekly rainfall ≥ 20 mm in East Champaran district, Bihar (data base: 1965-2012)

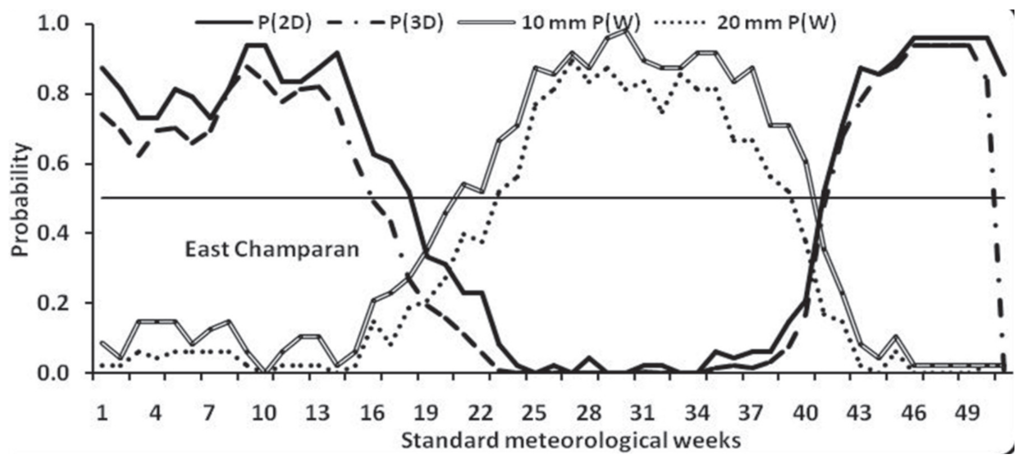

Fig. 2. Probabilities of receiving dry spell for consecutive two weeks, P(2D) and three weeks, P(3D) along with initial probability, P(W) for 10 and 20 mm threshold rainfall over East Champaran district, Bihar (data base: 1965-2012)

Conclusions

Selection of crops or variety must match with the water availability in the area, and scheduling of irrigation must follow the critical growing stages to avoid water stress. Hence, the cropping plan should be tailored on a rational basis with available rainfall resource of the district to enhance agricultural production. The findings of the study could help in identifying wetness or dryness conditions during growing season and thereby helping farmers to schedule irrigation needs or conserve excessive rainfall which can be used as supplemental irrigation for higher productions.

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