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An agroclimatological approach of predicting kharif rice yield using daily rainfall data: A case study for Purulia district of West Bengal

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ABSTRACT

Total seasonal rainfall being mostly sufficient during the rainfed *kharif* rice-growing period in the Purulia district of West Bengal, the crop is subjected to frequent water stress due to its uneven distribution. To assess the effective part of the total rainfall for *kharif* rice a daily rainwater balance approach has been followed to estimate effective rainfall (ER) against a given total rainfall (TR) during July, August and September and its contribution to rice yield in the Purulia district Twenty years of historical rainfall database across 8 different locations along with 13 years of historical rice yield data were analysed. ER for rice varied from 63-66% during these three rice-growing months. Coefficient of variability of monthly TR was much higher than the ER for the same period. ER during August showed maximum degree of association with rice yield (r = 0.78*). Degree of association between ER and yield has been higher than that with TR and thus ER is a better predictor of rice yield than TR. Three different multiple regression equations were tried using components of this rainwater balance to predict rice yield; one equation involving ER corresponding to July, August and September is recommended for its maximum goodness of fit.

Key words : Effective rainfall, rainwater balance, rice yield.

In West Bengal, optimum time for transplanting of *kharif* rice ranges from mid-July to mid-August depending upon availability of rainwater and other resources. In most districts of the state the total amount of rainfall received during the *kharif* rice-growing period is more than sufficient as far as water requirement of the crop is concerned. However, rice crop is most often exposed to water stress due to uneven distribution of rainfall and leads to yield reduction. A good number of literatures are available for predicting rice yield using periodical total rainfall during *kharif* rice growing period in the form of multiple regression type of equation (Khan *et al*.,1995; Agarwal *et al*., 1986; and Agarwal *et al*., 1980). Since substantial amount of rainfall during this period comes from intense shower and eventually lost as run-off, total rainfall of any periodicity has a definite limitation as predictor for rainfed *kharif* rice yield. So an investigation was carried out using the effective part of daily rainfall through a daily rainwater balance approach during this period taking care of daily evapotranspiration and percolation losses and maximum permissible submergence.

MATERIALS AND METHODS

Daily rain water balance

Historical daily rainfall data of 8 rain gauge stations of Purulia district of West Bengal, viz, Baghmundi, Barabazar, Hathwara, Hura, Jhalda, Kashipur, Manbazar and Para for the period 1981-2000 were collected from Agriculture Department, Govt. of West Bengal. A simple daily rainwater balance study, for the months of July to September was worked out to estimate monthly total run-off losses (TL), water deficit (TD) and effective rainfall (ER) for transplanted *kharif* rice crop with the following assumptions: a) a generalised value of combined daily evaporation, transpiration and percolation losses as 7 mm d^{-1}. Singh and Singh (2000) considered this value for whole of eastern India to find out stable rainfall period for rice. b) a standard and uniform bund height of 50 mm as the limit for maximum surface water storage in rice field beyond which there will be run-off loss of rainwater. A sample rainwater balance sheet including all its parameters for the month of July 1984 for the rain gauge station Jhalda is presented in Table 1. In this table, Column A indicates the storage of rainwater from the previous day (day, i-1), Column C indicates total of

Table 1: A sample daily rainwater balance sheet for the month of July, 1984 (Station: Jhalda, District: Purila, West Bengal).

Date	Storage from previous day (i-1) (mm	Rainfall today (day i) (mm)	Total water available (day i) (mm)	Storage at the end of the day i (mm)	Total water deficit at day i (mm)	Total run-off loss at day i (mm)	Total effective rain at day i (mm)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	0	17	17	10	0	0	17
2	10	3	13	6	0	0	3
3	6	2	8	1	0	0	2
4	1	0	1	0	6	0	0
5	0	10	10	3	0	0	10
6	3	38	41	34	0	0	38
7	34	0	34	27	0	0	0
8	27	3	30	23	0	0	3
9	23	4.5	27.5	20.5	0	0	4.5
10	20.5	11.4	31.9	24.9	0	0	11.4
11	24.9	7.4	32.3	25.3	0	0	7.4
12	25.3	8.5	33.8	26.8	0	0	8.5
13	26.8	3.2	30	23	0	0	3.2
14	23	8.2	31.2	24.2	0	0	8.2
15	24.2	0	24.2	17.2	0	0	0
16	17.2	34	50	43	0	1.2	32.8
17	43	8	50	43	0	1	7
18	43	19	50	43	0	12	7
19	43	1.4	44.4	37.4	0	0	1.4
20	37.4	0	37.4	30.4	0	0	0
21	30.4	11.4	41.8	34.8	0	0	11.4
22	34.8	48	50	43	0	32.8	15.2
23	43	21	50	43	0	14	7
24	43	0	43	36	0	0	0
25	36	3.4	39.4	32.4	0	0	3.4
26	32.4	1	33.4	26.4	0	0	1
27	26.4	0	26.4	19.4	0	0	0
28	19.4	0	19.4	12.4	0	0	0
29	12.4	6	18.4	11.4	0	0	6
30	11.4	34.4	45.8	38.8	0	0	34.4
31	38.8	0	38.8	31.8	0	0	0

Column A and B with the maximum limit of bund height (i.e., A+B <= 50 mm). Column D indicates storage at the end of day i after use of 7 mm of water, if available in Column C (i.e., C-7, with minimum value 0). Column E indicates deficit of water with respect to a uniform daily requirement of 7 mm (i.e., if C>= 7, E=0 or, if C<7, E = 7-C). Column F indicates horizontal run-off loss (50- {A+B}, when A+B>50 mm, i.e., the bund height). Column G indicates effective part of the rain corresponding to the day i which has either contributed to ET or percolation or has been stored in the plot, with the maximum limit of bund height, for utilisation on the next day. In this waterbalance study it has been indicated as Column B – Column F. Daily values of water deficit, run-off and effective rainfall for each station and database year were computed using computerised spreadsheet programme which was subsequently processed to monthly values.

Table 2: Summary of daily rainwater balance parameters of different raingauge stations of Purulia during the month of July, August and September for the period 1981-2000 (Figures in parenthesis indicate CV%)

Month	Parameter	Baghmundi	Barabazaar	Hathwara	Hura	Jhalda
July	TR	347.3 (32.8)	248.7 (41.5)	304.8 (33.0)	311.2 (34.1)	308.7 (41.5)
	TD	26.1 (87.5)	37.4 (78.3)	33.9 (81.7)	42.4 (76.2)	41.1 (99.1)
	TL	129.9 (73.4)	72.7 (115.6)	97.0 (72.5)	108.7 (69.7)	106.0 (84.7)
	ER	217.5 (13.8)	176.0 (18.0)	207.8 (18.6)	202.5 (17.9)	202.8 (24.4)
August	TR	303.3 (25.1)	211.5 (58.0)	285.4 (36.4)	283.1 (27.9)	307.1 (37.0)
	TD	16.5 (109.6)	69.6 (85.8)	23.4 (105.7)	18.3 (114.0)	19.3 (119.6)
	TL	106.8 (69.9)	75.3 (99.7)	97.7 (97.3)	100.4 (68.3)	119.9 (79.0)
	ER	196.5 (11.2)	136.2 (44.2)	187.7 (15.1)	182.7 (13.8)	187.3 (16.6)
September	TR	259.3 (43.2)	68.7 (94.4)	248.8 (55.6)	241.6 (56.1)	241.9 (56.6)
	TD	41.9 (101.3)	151.2 (26.6)	51.9 (90.1)	62.9 (69.3)	54.9 (68.0)
	TL	98.4 (99.9)	14.2 (254.3)	96.1 (107.5)	95.4 (111.0)	88.7 (124.0)
	ER	160.9 (29.9)	54.4 (65.3)	152.7 (34.2)	146.2 (33.5)	153.2 (35.2)

Table 3: Correlation between monthly totals of daily rainwater balance parameters with rainfed *kharif* rice yield at Purulia (combining all the stations)

Parameters	July	August	September
Total Rainfall (TR)	0.23	0.60*	-0.33
Total Deficit (TD)	-0.25	-0.62*	-0.08
Total Loss (TL)	0.17	0.42	-0.24
Effective rainfall (ER)	0.35	0.78*	-0.39

Correlation and regression studies

For the purpose of correlation and regression studies of these water balance parameters with rice yield, available rice yield data pertaining to those 8 rain gauge stations for the period 1986-1998 were collected from Bureau of Economics and Statistics, Govt. of West Bengal. Due to poor quality of yield data of the year 1995 & 96, these were deleted. Mean values of water balance parameters as well as yield data across 8 stations of Purulia district of each year were used as dataset for correlation and developing best fit regression equation for predicting rice yield.

RESULTS AND DISCUSSION

Water availability status during crop growth period

Summary of daily rainwater balance across 8 stations showed that total rainfall during July , August and September were 304.3, 274.8 and 220.5 mm, respectively out of which 199.4, 177.3 and 138.3 mm (63-65%) respectively were actually utilizable by the rice crop as effective rainfall (Table 2). The coefficient of variability of effective rainfall for any month and/ or station was always lower than the total rainfall corresponding to that month indicating thereby that ER gives better picture of rainwater availability to rice than total rainfall (TR). Assuming a daily water requirement of 7 mm (ET+P) and so a monthly requirement of

Table 4: Regression equations for predicting kharif rice yield using daily rainwater balance parameters.

No.	Regression equation
1.	Y = 2.23 (ER-Jul) + 9.39 (ER-Aug) – 0.55 (ER-Sep) + 212.6
2	Y = 10.04 (ER-Aug) + 498.2
3	Y = 1848.5 –0.02 (TR-Jul) + 2.33 (TR-Aug) –0.81 (TR-Sep)

around 200 mm it was noted that average rainfall in each month was much higher than this figure and nevertheless total water deficit in each month varied from as low as 16.5 mm to as high as 151.2 mm. This clearly shows the unevenness of rainfall distribution in Purulia district with respect to water requirement of rice. Another indicator of unevenness of rainfall distribution is the runoff (TL), value of which is much higher than the corresponding total deficit. This shows that had the total rainfall been evenly distributed, the deficit could very well be overcome in the season.

Correlation studies

Results on correlation coefficient between each daily rainwater balance parameters and yield of rice pooled over all the stations (Table 3) show that effective rainfall (ER) recorded higher degree of association with yield than the total rainfall (TR) of the corresponding period with its highest value (0.78) during the month of August. This clearly justifies the derivation of effective rainfall through rainwater balance estimation to get a clearer picture of water availability to rainfed *kharif* rice over total rainfall. All the parameters corresponding to the month of August exhibit an influence on rice yields than in other months. Weak negative correlation of TR and ER corresponding to the month of September with final rice yield suggests that increasing rainfall during reproductive stage may have a deleterious effect on rice yield.

Regressions analysis

In order to develop good prediction equation for rainfed *kharif* rice yield in the Purulia district, three different equations were studied using monthly rainwater balance parameters (Table 4). A multiple regression equation using ER values corresponding to July, August and September has been found to be the best in terms of goodness of fit since these independent variables could explain 69% of the variation in rice yield. Another simple linear regression was tried using the variable ER corresponding to August since it showed maximum degree of association (0.78) with yield. However, comparing the coefficient of determination value this equation rated inferior to the earlier one. Average deviation of the predicted yield by equation No.2 was the lowest (+/- 95.9 kg ha^{-1}) and nearly close to that predicted by the equation No.1 (+/- 106.2 kg ha^{-1}). However, equation No.1 is recommended in this case since the R^2 value is higher than that of the equation No.2 and ER of all the three months have been considered.

Thus it can be concluded that instead of using periodical total rainfall during crop growing season as a predictor variable use of effective rainfall corresponding to the months of July, August and September as assessed from the daily rainwater balance analysis is a better approach in predicting rainfed *kharif* rice yield.

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