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*Short Communication*

# Study on occurrence of drought in relation to rainfed rice productivity in Terai zone of West Bengal

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Rainfall plays an important role in agriculture as it can influence various stages of crop development, particularly in rice (Agarwal *et al.,* 1979). Rice is the staple food for the Asian populace and is the second-largest widely consumed cereal crop. 40 % of the area in India under rice cultivation is rainfed (Source: NRRI Research Bulletin No. 22). The Indian Subcontinent is fed by the South West Monsoon (SWM) occurring from June to September (Iyengar and Raghu Kanth, 2004). Weather fluctuations such as heavy rainfall at the onset, sudden breaks and early withdrawal of rainfall bring about unevenly distributed rainfall.

Precipitation is generally high in the Terai Zone occurring mostly during the SWM season. Despite being a region that receives heavy rainfall, Cooch Behar and two other districts in West Bengal are most affected by climate change (Ghosh *et al.,* 2017). The success or failure of rainfed rice is anticipated since it is positively determined by the SWM pattern (Kamble *et al.,* 2019). Weekly examination of rainfall is necessary since a dry spell of more than a week is injurious to rice (Srivastava *et al.,* 2000).

Cooch Behar district under Terai Zone of West Bengal was selected for the present investigation. The productivity data of rainfed rice for 1980-2014 and daily rainfall data of Cooch Behar was collected from Statistical Abstract, Govt. of West Bengal and IMD (Indian Meteorological Department) Pune, respectively. The rainfall data of four years were reported to be missing – 1993, 1994, 1999, and 2001 by the IMD. The present investigation is based on the datasets excluding the aforementioned missing years.

Firstly, a weekly sum for the standard meteorological week (SMW) from 3$^{rd}$ week of June to 2$^{nd}$ week of October i.e. 25$^{th}$ to 41$^{st}$ week was selected for calculating the 'n' week rainfall total where $2 \leq n \leq 16$. So the weekly total for every SMW$^{th}$ week where $5 \leq m \leq 41$ was prepared. These totals add up n-week successive rainfall during the SMW. For every value of 'n', the minimum rainfall total observed per year for different 'm' values was chosen. If n= 4, there are 14 rainfall totals, each consisting of 4 consecutive week totals and for this, the minimum rainfall total value is selected.

### *Drought threshold*

A drought value is the minimum rainfall amount beyond which a drought condition exists. The minimum rainfall for the $n^{th}$ week where $2 \leq n \leq 16$ were plotted against the deviation from the standard rainfed rice yield rate (kg ha$^{-1}$). The standard rainfed rice yield rate was obtained by taking the productivity mean of all the years. There are 31 points (Fig. 1) and each one of them is indicative of a year. The minimum amount of consecutive n-week rainfall total past which at least half the points lie over the line of standard yield rate is called the drought threshold value. The threshold values for all the 'n' weeks are calculated.

### *Models fitted to drought threshold values*

To this data, several models- Inverse, Logarithmic, Linear, Quadratic and Cubic were fitted. The best fitted model was selected for obtaining the drought base values. The drought base values estimate the amount of rainfall below which drought conditions may exist. This amount is the minimum rainfall in a particular region for a given number of successive weeks. So, for a given year, if the total rainfall of 'n' weeks for any $m^{th}$ week is lower than the drought base value, it is indicative of a crop-specific drought. Different duration deficits in a single year are recorded and these frequencies denote whether a year experienced drought or not.

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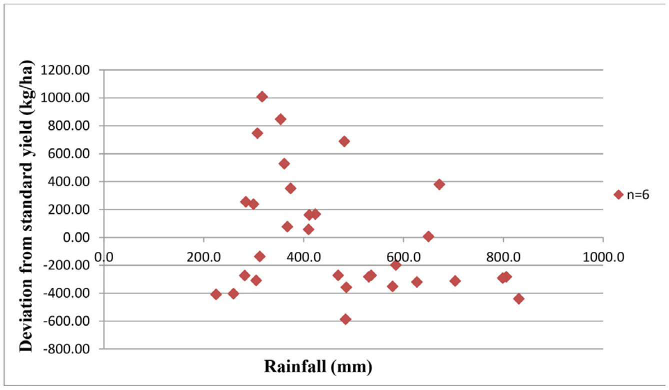


**Fig. 1:** Deviation from standard yield rate for n=6 under different rainfall regime

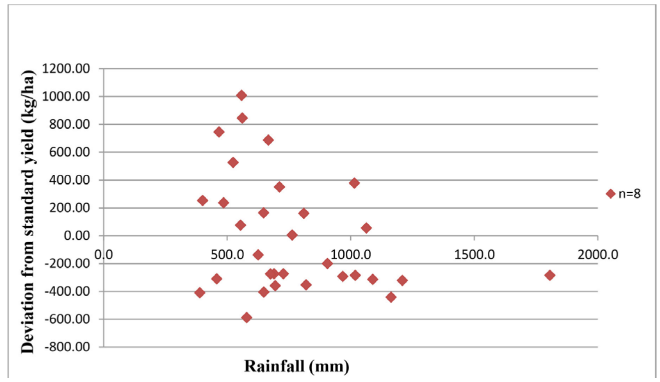


**Fig. 2:** Deviation from standard yield rate for n=8 under different rainfall regime

**Table 1:** 'n' - Week drought threshold values and base values (mm)

| n | Threshold value (mm) | Base value (based on quadratic model) (mm) | n | Threshold value (mm) | Base value (based on quadratic model) (mm) |
|---|---|---|---|---|---|
| 2 | 0 | 161.57 | 9 | 514.9 | 546.97 |
| 3 | 53.2 | 91.61 | 10 | 618.8 | 768.72 |
| 4 | 121.6 | 63.32 | 11 | 741.1 | 1032.14 |
| 5 | 175.7 | 76.70 | 12 | 873.3 | 1337.24 |
| 6 | 354.1 | 131.76 | 13 | 2017.4 | 1684.01 |
| 7 | 362.3 | 228.49 | 14 | 2332.8 | 2072.45 |
| 8 | 400.5 | 366.89 | 15 | 2693.1 | 2502.57 |
| | | | 16 | 2780 | 2974.36 |

**Table 2:** Models fitted to drought threshold values

| Type | Equation | | M.S.E. | t- value | | |
|---|---|---|---|---|---|---|
| | | | | (p value) | (p value) | (p value) |
| Inverse | $Y = 1742.777 - 5083.674/X + e$ | 0.387 | 649451.5 | -2.867 (0.013) | | |
| Logarithmic | $Y = -1632.740 + 1256.197(\log X) + e$ | 0.621 | 401817.3 | 4.614 (0.000) | | |
| Linear | $Y = -872.299 + 200.913X + e$ | 0.820 | 190522.4 | 7.702 (0.000) | | |
| Quadratic | $Y = 426.522 - 174.147X + 20.837X^2 + e$ | 0.950 | 57142.1 | -2.542 (0.026) | 5.599 (0.000) | |
| Cubic | $Y = 5.071 + 32.053X - 5.725X^2 + 0.984X^3 + e$ | 0.954 | 57296.8 | 0.145 (0.887) | -0.210 (0.837) | 0.984 (0.346) |

***Probability of drought***

The relative frequency (Frequency/Number of years) of drought incidences offers an estimate of the probability of crop specific drought. The 'n' week total rainfall is compared with the base value for every week and cumulative frequency counted over the years for every value that is lesser than the base value gives the crop-specific drought probability.

The deviations from standard yield rate are represented by points on the scatter plots given in Fig. 1 and Fig. 2 for n=6 and n=8. For n=6, the drought threshold value is 354.1 mm. When the total rainfall amount for any six successive weeks starting from 25$^{th}$ to 36$^{th}$ SMW whether it is 25 to 30 or, 26 to 31 and so on becomes lower than 354.1 mm, then this situation is representative of a drought condition in the corresponding year. It can be understood that with every increasing 'n' weeks, drought threshold values escalate accordingly.

The best-fitted model was found to be the quadratic model. Drought threshold values obtained from the plot were fitted in the quadratic model to get the predicted drought base values as given in Table 1. The quadratic model has the lowest MSE value (57142.131) with high $R^2$ (0.95). Also, both the regression coefficients (b1 and b2) are significant (Table 2) for the quadratic model. For the base value of n=3, if the three weeks consecutive total of any $m^{th}$ week in a year is found to be less than 91.61 mm (the quadratic model base value), then there exists a rainfed rice specific drought of 3 weeks long in Cooch Behar district of West Bengal.

**Table 3:** Probability of drought occurrence of different week duration corresponding to the growth stages

| Week No. (m) | Growth Stages of rice | Week duration (n) | | | |
|---|---|---|---|---|---|
| | | 2 | 3 | 10 | 11 |
| 25. | Sowing to Germination | 0.065 | 0 | 0 | 0.065 |
| 26. | Emergence to Seedling | 0.161 | 0 | 0.032 | 0.065 |
| 27. | Seedling (Transplanting) | 0.097 | 0 | 0.065 | 0.065 |
| 28. | Tillering | 0.226 | 0 | 0.032 | 0.129 |
| 29. | Tillering | 0.290 | 0 | 0.065 | 0.129 |
| 30. | Tillering | 0.290 | 0.065 | 0.032 | 0.226 |
| 31. | Stem Elongation | 0.355 | 0 | 0.097 | 0.290 |
| 32. | Panicle Initiation | 0.355 | 0.032 | 0.161 | |
| 33. | Booting | 0.226 | 0 | | |
| 34. | Heading | 0.323 | 0 | | |
| 35. | Flowering | 0.419 | 0.032 | | |
| 36. | Grain filling | 0.323 | 0 | | |
| 37. | Milking | 0.452 | 0.065 | | |
| 38. | Doughing | 0.484 | 0.097 | | |
| 39. | Yellowing | 0.710 | 0.097 | | |
| 40. | Ripening | 0.806 | | | |
| 41. | Maturity | | | | |

In Table 3, the probability of drought of n - week duration beginning with any 'm' week are presented for 25 during the rainfed rice-growing season. The probability of n=2 for m=28, m=37 is 0.226, 0.452, respectively. This implies that the probability of a two-week-long duration drought occurring from the 28th week and 37th week for a given year is 0.226 (22.6%) and 0.452 (45.2%). It also suggests that a drought of this kind can occur every = 4.425 years and 1/0.452= 2.21, i.e. approximately every 4 and 2 years, respectively. The rice development phases that are affected most by 2 week duration drought are flowering to grain filling (0.419), milking to dough (0.452), dough to yellowing (0.484), yellowing to ripening (0.710), and ripening to maturity (0.806). Also, Cooch Behar is seen to experience a 10 week long rainfed rice specific drought from stem elongation to ripening (9.7%), and panicle initiation to maturity (16.1%).

The probability of occurrence of drought gives the estimates of the frequency of drought of different duration for rainfed rice in Cooch Behar. Understanding the rainfall inconsistency during the rice growing stages can help plan adaptive strategies to cope with the effects on crop productivity.

***Conflict of Interest Statement:*** The author(s) declare(s) that there is no conflict of interest.

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