551.577.38 : 633.18 : 633.11 (541.4)

DROUGHT INTENSITY AND YIELDS OF RICE AND WHEAT IN DRY TRACTS OF BIHAR

1. Drought and floods are the two major natural disasters that effect crop yields. Depending on the purpose of study the drought situations may be categorized into different types. Climatic water balance provides an estimate of water availability to crops in relation to potential evapotranspiration (PET) and rainfall. By employing water balance approach Patel *et al.* (1986) studied the influence of agricultural droughts in different growth phases on yield of *kharif* crops at Raipur. Victor and Sastry (1984) have also used the water balance method to study agricultural drought in relation to soil moisture index with respect to *kharif* crops grown in Delhi region.

This study is confined to the two crops grown under rainfed conditions in the Bihar state. Crop yields at the six selected stations from dry farming tract of Bihar state were studied in relation to drought intensities. Weekly water balances for rice and wheat-growing seasons were computed and drought intensities were calculated. Yearly crop yields were studied in relation to droughts of different intensity.

2. The daily values of weather parameters like maximum and minimum temperatures and rainfall of last 20-25 years were collected from IMD Pune. The weekly values were calculated and arranged according to standard meteorological weeks. The original method of Thornthwaite (1948) was adopted here to estimate potential evapotranspiration using tables and nomogram published by Thornthwaite and Mather (1957). Climatic water balance on weekly basis for individual years was calculated using the procedure developed by Thornthwaite and Mather (1957). Weekly potential evapotranspiration (PET), actual evapotranspiration (AET), and water deficit (WD) were derived from this method.

The water requirement at different growth stages of the crop was obtained by multiplying reference crop ET by the crop coefficient. Based on the crop data and personal discussion with the scientists the growing period and duration of the growth stages of rice and wheat crops in the region were identified and used in the study. The crop coefficients for rice and wheat, suggested by Doorenbos and Pruitt (1977) and Doorenbos and Kassam (1979) respectively were adopted here after adjusting to corresponds to the growth stages. The adjusted crop coefficients at different growth stages of rice and wheat with their durations in weeks are shown in Table 1(a).

TABLE 1(a)

Crop coefficients and growth stages

Crop	Stages	Phenological stages	Duration (weeks)	Crop coefficients
Rice	I	Vegetative	10 : 4*	0.90
			: 6	1.10
	II	Reproductive	2	1.05
	III	Grain filling and Maturity	5	0.95
Wheat	I	CRI	3	0.30
	II	Vegetative	8	0.5-1.0
	III	Flowering	3	0.90
	IV	Maturity	3	0.60-0.30

* = There are two parts in vegetative phase comprising of 4 and 6 weeks.

TABLE 1(b)

Drought intensities

Departure of crop water deficit index value from the median	Drought intensity
0-<1/2σ	Mild
1/2σ-σ	Moderate
σ-2σ	Severe
>2σ	Disastrous

Where the σ is the standard deviation of the crop water deficit index values.

The stress condition of the crop, as suggested by Hiller and Clark (1971) was computed by the relation (1-AET/PET) × 100. The weekly values of the aridity index were summed over each growth stage and also for the growing periods of the each crop to provide an accumulated aridity index for the crop seasons. Since this index reflects climatic water deficit in the seasons or in the different growth stages of crops, it is referred to as "crop water deficit index (CWDI)". Drought years were segregated on the basis of their severity following the procedure adopted by Subrahmanyam and Sastri (1969). The levels of classification are given in Table 1(b).

3. *Climatic water balance* - Average weekly water balance for rice and wheat growing seasons were computed following the Thronthwaite and Mather (1957) method for each station and water surplus or water deficit in any week during the crop season is determined and shown in Table 2.

TABLE 2

Pattern of water availability and duration

Station	Patna	Gaya	Bhagalpur	Dumka	Ranchi	Hazaribagh
Water Surplus(mm)	Nil	Nil	Nil	196	528	286
Duration (week)	Nil	Nil	Nil	32-40th (9 weeks)	29-40th (12 week)	30-41st (12 weeks)
Water deficit(mm)	860	968	880	726	486	490
Duration(weeks)	1 - 26th & 41 - 52nd (38 week)	1-26th & 38-52nd (41week)	1-25th & 38-52nd (40 week)	1-25th & 41-52nd (37 week)	1-24th & 43-52nd (34week)	1-22nd & 42-52nd (33week)

TABLE 3

Limit of crop water deficit index for drought categorization

Category of drought	Rice	wheat
	Patna	
No drought	< 330	< 1067
Mild	331-420	
Moderate	421-509	
Severe	> 510	
	Gaya	
No drought	< 367	< 1045
Mild	368-448	1046-1167
Moderate	449-528	1168-1289
Severe	> 528	> 1290
	Bhagalpur	
No drought	< 336	< 1177
Mild	367-454	1178-1247
Moderate	455-542	1248-1317
Severe	> 543	> 1318
	Dumka	
No drought	< 192	< 1221
Mild	193-288	1222-1286
Moderate	289-374	1257-1351
Severe	> 374	> 1352
	Ranchi	
No drought	< 97	< 901
Mild	98-146	902-981
Moderate	147-195	982-1061
Severe	> 195	> 1062
	Hazaribagh	
No drought	< 167	< 928
Mild	168-263	929-1035
Moderate	264-359	1036-1132
Severe	> 390	> 1133

TABLE 4(a)

Mean productivity (kg/ha) of rice and wheat crops in six stations of Bihar

Station	Rice	Wheat
Patna	1318(27)	1727(25)
Gaya	993(31)	1220(25)
Bhagalpur	1124(23)	1232(30)
Dumka	1016(18)	1333(27)
Hazaribagh	708(31)	796(55)
Ranchi	688(27)	969(40)

Figures in parenthesis indicate c.v. (%).

TABLE 4(b)

Ranking of stations according to productivity and yield variability

Crop	Stations
	Productivity (from highest to lowest)
Rice	Patna, Bhagalpur, Dumka, Gaya, Hazaribagh, Ranchi
Wheat	Patna, Dumka, Bhagalpur, Gaya, Ranchi, Hazaribagh
	Variability (from lowest to highest)
Rice	Dumka, Bhagalpur, Ranchi, Patna, Hazaribagh, Gaya
Wheat	Patna, Gaya, Dumka, Bhagalpur, Ranchi, Hazaribagh

In general the analysis shows that the station Dumka, Ranchi, Hazaribagh, have large surplus and there is no need of supplementary irrigation for rice crop. Rainfed crop can be taken without any adverse effect. The stations Patna, Gaya and Bhagalpur show mild seasonal moisture deficit with no water surplus in any week during the growing season (*Kharif* and *Rabi)* crops can not be grown without supplementary irrigation. Of all the stations

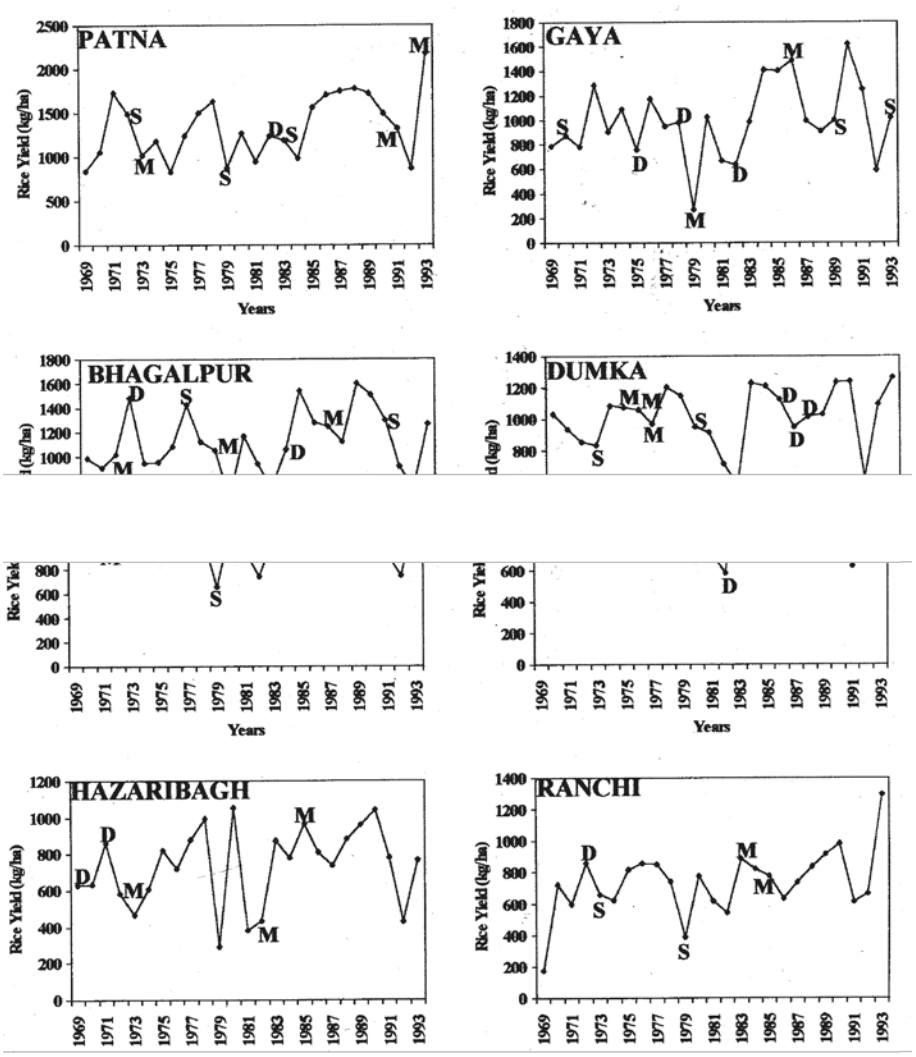

Fig. 1(a). Rice yield since 1969 at different stations and drought occurrence

considered, with respect to rainfed crops, Gaya is relatively drier with large deficit (Table 2).

3.1. *Crop water deficit index (CWDI)* - The values of CWDI derived from weekly values of water balance parameters for six stations have sown that the crop water deficit index ranged from 124 to 857 in case of rice and 609 to 1351 for wheat at Patna. Values of similar magnitudes are observed at other stations also. A lower value of this index signifies "no drought" condition and the higher the value of this index, the higher the crop water deficit during crop growth period.

3.2. *Classification of drought of rice, wheat cropping seasons in relation to crop water deficit index* - Standard deviation (S.D.) and median of the seasonal index values for both crops at each of the stations for the data period used in this analysis were worked out. The amplitude of the departure of CWDI from the median was utilized to categorize drought years. The limits of crops deficit index so obtained in respect of rice and wheat crops are given in Table 3. Comparison between yearly drought intensity and intensity of drought derived by CWDI show interesting results that yearly drought intensity is not wholly reflected in seasonal droughts. In

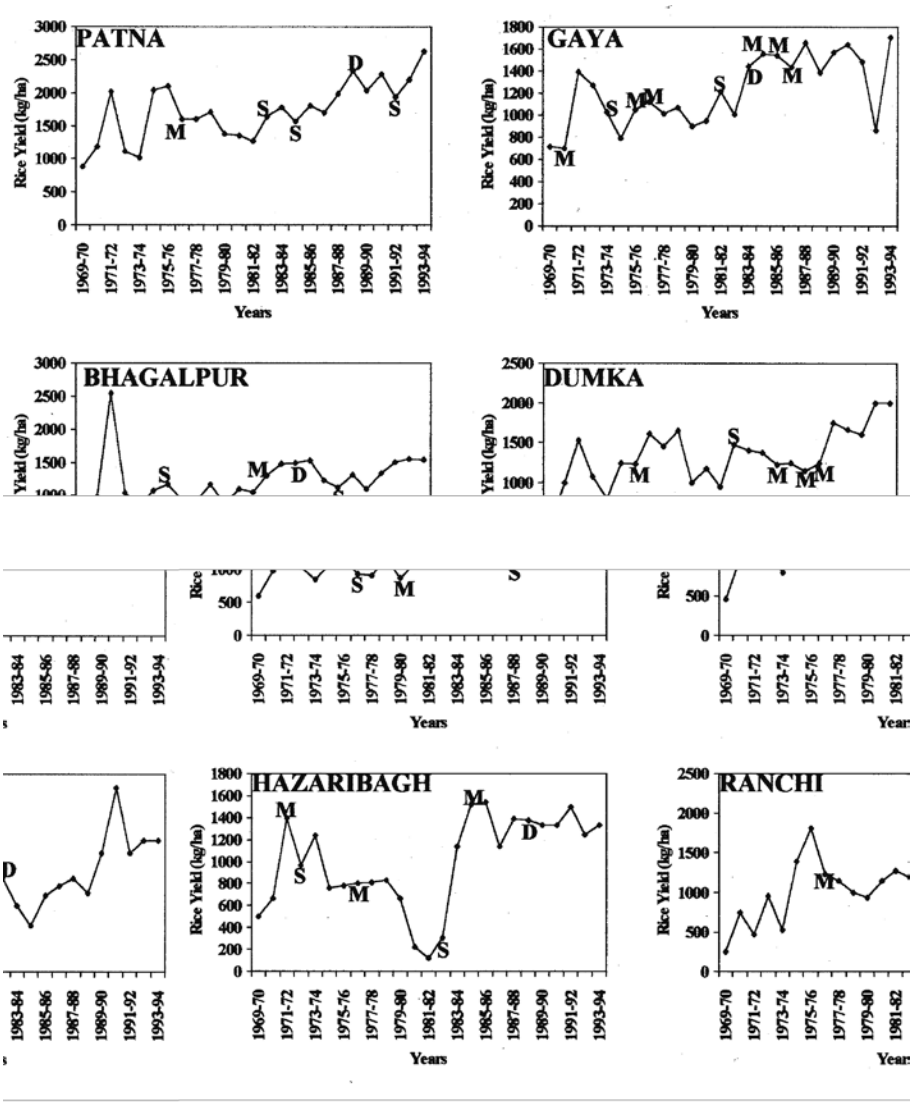

Fig. 1(b). Wheat yield since 1969 at different stations and drought occurrence

certain occasions, there is a slight time lag between the time of occurrence of water deficiency and droughts.

3.3. *Crop yield and drought index* - The area and production of the crop in different stations were collected from Department of Statistics & Evaluation, Bihar for the period from 1969-70 to 1992-93, the average yield and the mean and coefficient of variation were calculated for rice and wheat crops for all the stations under study. The mean productivity (kg/ha) and coefficient of variation (%) are presented in Table 4(a). The result indicates that in general, the productivity ranges between 688 to 1318kg/ha for rice and 796 to 1727 kg/ha for wheat crops at the different stations. In order to assess the relative adaptability of the crops at the different stations they have been ranked according to productivity and its variability and sown in Table 4(b).

From the results it is seen that Patna has the highest mean productivity for both rice (1318 kg/ha) and wheat (1727 kg/ha) crops. The lowest mean productivity for rice is observed at Ranchi (688 kg/ha) and for wheat it is lowest at Hazaribagh (796 kg/ha), although, the rainfall is high for these two stations. Among the six stations, the coefficient of variation in rice productivity was lower (18-31%) as compared to that of wheat (25-55%). Variability

in wheat productivity is the highest for the station Hazaribagh and lowest for Patna as well as Gaya. Variability in crop productivity for rice is highest at Gaya and Hazaribagh while Dumka has lowest variability.

For examining the effect of fluctuations of rainfall and CWDI on crop yields, an analysis of rice and wheat yields from 1969 to 1993 is made and shown in Figs. 1(a&b). The intensity of agricultural drought is categorized as Moderate (M), Severe (S) and Disastrous (D).

It is interesting to note from the figures that for all the six stations, drought intensity and yield is not corresponding to each other. Some times the decrease in yield due to drought is reflected in yield reduction but the decrease in yield is not uniform in all the years. In general, there is an increasing trend in yield of rice and wheat crops and no direct relationship between drought intensity and yields could be established because crop yields are not solely determined by weather. Other factors like soil type of a particular station, variety of crop, agronomic practices followed in that region, incidence of diseases and pests, also affect the yields of crops. Similar drought situation did not follow similar reduction in yields at these stations. This is due to the fact that there is a general increase in the yields over the years, which is mainly due to technological changes like increase in fertilizer application/ pesticides/ improved seeds etc. For example, station Ranchi receives highest amount of rainfall among the stations under study but due to sandy loam soil type and topographical features, productivity of rice and wheat is very less. Hence an integrated approach for yield prediction is necessary. One should also take into account the soil type, time of sowing and harvesting, agronomic practices, fertilizer application and other technological changes, in addition to meteorological/water balance parameters.

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