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VALIDATION OF DRAS MODEL FOR IRRIGATION OF WHEAT

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Abstract

The study was conducted to validate the Drought Assessment (DRAS) model developed by the Center for Environmental and Geographic Information Services (CEGIS) for irrigation scheduling of wheat (variety: Shatabdi). The performance of the model was compared with the results obtained from the BARI recommended irrigation schedule. The field experiments were carried out during the years 2005-2006 through 2007-2008 in two agro-ecological zones. The locations were RARS, Jamalpur under agro-ecological zone 9 and farmers' field of FSR site, OFRD, Barind, Rajshahi under agro-ecological zone 26. Six different irrigation treatments including one rainfed with three replications were considered for the study. In respect of yield, BARI recommended irrigation practice performed better in Jamalpur (3.642 t/ha on average). Application of net irrigation requirement (NIR) as per DRAS model based on reported value yielded highest (3.598 t/ha on average) in the Barind area, Rajshahi. However, the yields from all irrigated treatments were very close to each other. From three years' study, the model performance was found quite satisfactory for irrigated wheat, especially in drought prone areas like Barind, Rajshahi. In respect of water productivity, the model performed almost similar to the BARI recommended practice in Jamalpur. It performed better in Barind region where irrigation water was used by the crop more efficiently.

Keywords: DRAS model, irrigation, wheat.

Introduction

To meet the requirement of cereal, wheat may be a viable substitute. It is highly responsive to irrigation water. With only 2 to 4 irrigations and through proper management, wheat yield can be increased by 50 to 100 percent. The irrigations at crown root initiation, maximum tillering and grain filling stages were found beneficial and also essential in increasing further grain yield of wheat (Rashid, 1994).

The month-wise distribution of rainfall in Bangladesh indicates that the wheat growing season (November-March) is the driest period of the year. The soil moisture is depleted rapidly in the later part of the crop if there is scanty or no rainfall during the wheat growing period. Soil moisture stress is reported to adversely affect the wheat yield (Rashid and Islam, 1986).

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Poor supply of water and lack of proper irrigation scheduling are the main problems associated with the farmers (Saunders, 1991). Wheat generally suffers from water scarcity both in normal and dry years. Uneven distribution of rainfall throughout the year and water scarcity during the dry season affect the crop yield even in the average rainfall years. The drought could be managed efficiently through the adoption of well irrigation management practices. The DRAS model can be a useful tool to predict the net irrigation requirement (NIR) for wheat.

The model predicts the NIR on decade basis. When the crop suffers from water stress condition, the model prescribes an irrigation schedule for the crop. As the soil texture and type vary from field to field significantly, the model calculates the NIR for different land horizons. It also takes into account the soil characteristics and climatic conditions. Soil series-wise irrigation schedule is of great importance for the farmers for appropriate irrigation measures and this information can be disseminated through upazilla extension services.

Drought Assessment Model for wheat is a new concept in the traditional agriculture of Bangladesh. The framework of the Drought Assessment Model is described in details in BARC (2001). The DRAS model is developed by CEGIS (Centre for Environmental and Geographic Information Services) for predicting net irrigation requirement (NIR) and yield loss for different rice and non-rice crops on the basis of climatic, soil and cropping parameters. The CEGIS developed the model to predict the net irrigation requirement (NIR) and decided to validate it in the research as well as in the farmers' field. The present study was an attempt to validate the model for wheat crop. The specific objectives of the study were:

(i) to validate the model with field data at different locations;

(ii) to compare the model predicted NIR with the BARI recommended water needs for wheat cultivation;

(iii) to recommend the best practice for a specific location.

Materials and Method

Wheat *(Triticum aestivum* L.) cv. Shatabdi (BARI Gam 21) was used as the test crop for the study. It is a high yielding variety released by the Wheat Research Centre, BARI (WRC, 2003). It performs better even in some delayed planting. It is semi-heat tolerant and is suitable to cultivate after harvest of transplanted Aman rice and can be cultivated throughout the country.

The experiment was carried out during the *rabi* seasons of the years 2005-06 through 2007-08. The field studies were conducted at RARS farm, Jamalpur and farmer's field of FSR site, OFRD, Barind, Rajshahi. Jamalpur site falls under Agro-ecological Zone 9 (Old Brahmaputra Floodplain). The texture of the sub-soil is clay loam over and under lain by clay loam and loam, respectively. The field capacity of the soil is 30% and the bulk density is 1.45 gm/cc. Rajshahi soil falls under Agro-ecological Zone 26 (High Barind Tract). The sub-soil texture is clay loam over and under lain by clay loam. The bulk density of the soil is 1.51 gm/cc and the field capacity 31.5%. The plot sizes were 4m × 5m in Jamalpur and 3m × 3m in Rajshahi. The experiment was arranged in a randomized complete block design (RCBD) with three replications. At all sites, fertilizers were applied as per recommended doses at the rate of 100, 35, 25, and 22 kg/ha of N, P, K, and S, respectively (BARI, 1999). Seeds were sown in second half of November during all the study years. The seed rate was 120 kg/ha. The crop was harvested in March of the cropping season. Soil moisture status in every plot was monitored by gravimetric method before each irrigation. BARI recommended irrigation treatment plots were irrigated upto field capacity of the soil and the other plots were irrigated as per recommendation of DRAS model. Yield and yield contributing parameters viz. plant height, spike length, grains per spike, 1000-grain weight, and grain yield were recorded.

The following treatments were used in the study;

T_1 = No irrigation.

T_2 = Application of irrigation based on BARI recommended practice (irrigation at 21, 45, and 65 days after sowing).

T_3 = Application of net irrigation requirement (NIR) as per DRAS model based on reported value.

T_4 = Application of NIR as per DRAS model based on actual field data.

T_5 = Application of cumulative NIR as per DRAS model based on reported value.

T_6 = Application of cumulative NIR as per DRAS model based on actual field data.

Results and Discussion

As mentioned earlier, the project was implemented in three *rabi* seasons of 2005-2006, 2006- 2007, and 2007-2008 years. But to avoid duplication of similar tables and discussion, only the achievements of 2007-2008 have been discussed in details in Table 1-6. Average results of three study years are also incorporated and discussed in Table 7-9.

The results obtained from the field study conducted during 2007-08 season at two sites are presented in Table 1 to 4. Table 1 contains the yield and yield contributing parameters of different treatments of Jamalpur site. As seen from Table 1, major agronomic parameters like plant height, spike length, and number of grains per spike were influenced significantly by different irrigation regimes. However, 1000-grain weight did not show any significant difference among

Table 1. Yield and yield contributing characters of wheat in different treatments during 2007-2008 at Jamalpur site.

Treatment	Plant height (mm)	No. of spikes/ m^2	Spike length (mm)	No. of grains/ spike	1000-grain wt (g)	Grain yield (t/ha)	Yield increase over T_2 (%)
T_1	842c	284	72.3b	25.9d	44.5	**2.917c**	-29.15
T_2	952a	307	87.7a	34.7ab	46.5	**4.117a**	-
T_3	936ab	302	85.7a	35.0a	45.4	3.983ab	-3.25
T_4	966b	325	82.7a	33.3abc	46.3	3.742b	-9.11
T_5	945ab	298	82.3a	31.6 c	47.0	3.808b	-7.51
T_6	932ab	307	85.3a	32.7bc	46.7	3.933ab	-4.47
CV (%)	1.78	4.62	5.98	3.72	4.18	4.44	-
LSD	33.24	NS	8.88	2.18	NS	0.304	-

the treatments. This result indicates that irrigation did not affect the size of the grains very much. In respect of grain yield, treatment T_2 (BARI recommended practice) performed better (4.117 t/ha) in Jamalpur. However, the yield decrease of the model based treatments from that of BARI recommended practice was very low (less than 10 percent). The rainfed treatment produced the lowest yield (2.917 t/ha) and differed significantly from irrigated treatments. Table 2 shows the effect of irrigation on yield and yield contributing parameters of the crop at Rajshahi site. A distinct effect of irrigation on plant height, spikes/ m^2, grains/spike and yield was observed. The trend of yield is somewhat different from that observed in Jamalpur. Treatment T_4, produced the highest yield (4.153 t/ha) in Rajshahi site although no significant difference was observed among the irrigated treatments.

Table 2. Yield and yield contributing characters of wheat in different treatments during 2007- 2008 at Rajshahi site

Treatment	Plant height (mm)	No. of spikes/ m^2	Spike length (mm)	No. of grains/ spike	1000-grain wt (g)	Grain yield (t/ha)	Yield increase over T_2 (%)
T_1	922c	238b	95c	35.1c	45.1	2.389b	-37.07
T_2	970ab	304a	103ab	43.7a	45.3	3.803a	-
T_3	l000a	312a	100b	41.2b	46.3	3.833a	0.79
T_4	995a	317a	106a	44.6a	45.7	**4.153a**	9.20
T_5	983ab	290 a	107a	45.5a	46.6	3.930a	3.34
T_6	967a	296a	106a	45.8a	46.0	3.861a	1.53
CV (%)	1.32	4.73	2.64	3.65	2.23	9.05	
LSD	23.4	11.6	4.95	2.84	NS	0.625	

Table 3 shows the water use and water productivity of the treatments at Jamalpur site. It should be noted here that T_3 and T_4 received the highest number of irrigations (10 irrigations each). So, the least amount of drought was imposed on those treatments. But T_4 produced lower yield (3.742 t/ha) than T_3 (3.983 t/ha). However, higher water was used by T_3 (330 mm) than T_4 (295 mm). It should be noted that both the treatments T_5 and T_6 received the same number of irrigations (4 irrigations each) although they used different amount of water. Table 3 reveals that lesser the water use, higher the productivity, and it is the highest in treatment T_1 (rainfed).

Table 3. Total water use (TWU) and water productivity (WP) of different treatments during 2007-2008 at Jamalpur site.

Treatment	No. of irrigation	Irrigation water (mm)	Effective rain fall (mm)	Soil moisture deficit (mm)	Total water use (mm)	Yield (t/ha)	Water productivity (kg/m^3)
T_1	0	0	**83**	59	**159**	2.917	1.831
T_2	3	140	83	43	291	4.117	1.415
T_3	10	182	83	54	330	3.983	1.207
T_4	10	144	83	29	295	3.742	1.269
T_5	4	195	83	34	**336**	3.808	1.133
T_6	4	154	83	50	310	3.933	1.269

Table 4 shows the water use and water productivity of the treatments at Rajshahi site. Since there was a reasonable amount of rainfall (83 mm in Jamalpur and 60 mm in Rajshahi) during the cropping season, the rainfed treatment produced comparatively high yields (2.917 t/ha at Jamalpur and 2.389 t/ha in Rajshahi) during 2007-2008 cropping season. The rainfed treatment showed the highest water productivity at both Rajshahi and Jamalpur sites (Table 3 and 4).

Table 4. Total water used and water productivity of different treatments during 2007-2008 at Rajshahi site.

Treatment	No. of irrigation	Amount of irrigation applied (mm)	Effective rain fall (mm)	Soil moisture deficit (mm)	Total water use (mm)	Yield (t/ha)	Water productivity (kg/m^3)
T_1	0	0	60	52	112	2.389	2.13
T_2	3	192	60	36	288	3.803	1.33
T_3	10	216	60	47	312	3.833	1.25
T_4	10	184	60	22	276	**4.153**	1.51
T_5	4	216	60	27	303	3.930	1.30
T_6	4	184	60	43	287	3.861	1.35

Economic analysis was done for both the study sites. The results are summarized in Table 5 and 6. All variable cost items were considered as per the market values to estimate the total variable cost (TVC) for different treatments. Wheat cultivation using BARI recommended practice (treatment T_2) was found

Table 5. Comparative cost and return from different treatments in Jamalpur during 2007- 2008.

Item	Different irrigation sequences					
	T_1 (Tk/ha)	T_2 (Tk/ha)	T_3 (Tk/ha)	T_4 (Tk/ha)	T_5 (Tk/ha)	T_6 (Tk/ha)
Human Labour	12240	12600	12720	12720	13440	13440
Land preparation	3000	3000	3000	3000	3000	3000
Seeding	4950	4950	4950	4950	4950	4950
Manure	8000	8000	8000	8000	8000	8000
Fertilizers						
Urea	1356	1356	1356	1356	1356	1356
TSP	3816	3816	3816	3816	3816	3816
MP	2368	2368	2368	2368	2368	2368
Gypsham	420	420	420	420	420	420
Irrigation	-	2805	3094	2550	3315	2616
Total variable cost	36150	39315	39724	39180	40665	39968
Gross return	93344	131744	127456	119744	121856	125856
Gross margin	57194	92429	87732	80564	81191	85888
BCR	2.58	3.35	3.21	3.06	3.00	3.15

Table 6. Comparative cost and return from different treatments in Rajshahi during 2007-08.

Item	Different irrigation sequences					
	T_1 (Tk/ha)	T_2 (Tk/ha)	T_3 (Tk/ha)	T_4 (Tk/ha)	T_5 (Tk/ha)	T_6 (Tk/ha)
Human Labour	12240	12600	12720	12720	13440	13440
Land preparation	3000	3000	3000	3000	3000	3000
Seeding	4950	4950	4950	4950	4950	4950
Manure	8000	8000	8000	8000	8000	8000
Fertilizers						
Urea	1356	1356	1356	1356	1356	1356
TSP	3816	3816	3816	3816	3816	3816
MP	2368	2368	2368	2368	2368	2368
Gypsham	420	420	420	420	420	420
Irrigation	-	3264	3672	3128	3672	3128
Total variable cost	36150	39774	40302	39758	41022	40478
Gross return	77404	125500	126490	137049	129690	127413
Gross margin	41254	85726	86188	97291	88668	86935
BCR	2.14	3.16	3.14	3.45	3.16	3.l5

comparatively profitable (highest BCR, 3.35) than the model based practices in Jamalpur. However, a model based treatment T_4 (application of NIR as per DRAS model based on actual field data) performed best in respect of profitability (highest BCR. 3.45) in Barind, Rajshahi.

Three years' combined results and discussion

The study was conducted during three consecutive years from 2005-2006 to 2007-2008. Grain yield and total water use (TWU) by different treatments during three study years at two locations are presented in Table 7 and 8. Average grain yield and TWU along with water productivity (WP) are also shown in the same tables. Some variations in the performances of the treatments were observed in two locations. Treatment T_2 (BARI recommended irrigation practice) yielded highest (3.648 t/ha on average) at Jamalpur site (Table 7), but the treatments based on the DRAS model (T_3, T_3, T_5, and T_6) performed better at Rajshahi site (Table 8). However, the yield difference among the irrigated treatments was very low (below 10%). In respect of crop water use, no distinct variation was observed among the irrigated treatments. At both the study sites, the treatment T_4 (application of NIR as per DRAS model based on actual field data) and treatment T_6 (application of cumulative NIR as per DRAS model based on actual field data) used irrigation water more efficiently than the other irrigated treatments. So, the water productivity for these treatments was comparatively high (Table 7 and 8).

Table 7. Yield, total water use and water productivity of different treatments at Jamalpur site.

Treatment	Year 2005-2006		Year 2006-2007		Year 2007-2008		Average yield (t/ha)	Average TWU (mm)	Water productivity (kg/m^3)
	Yield (t/ha)	TWU (mm)	Yield (t/ha)	TWU (mm)	Yield (t/ha)	TWU (mm)			
T_1	1.652	88	1.989	122	2.917	159	2.186	123	1.92
T_2	3.685	238	3.142	340	4.117	291	3.648	290	1.34
T_3	3.415	208	2.234	347	3.983	330	3.544	295	1.20
T_4	3.320	203	3.399	272	3.742	293	3.487	256	1.36
T_5	3.569	231	3.030	319	3.080	336	3.469	295	1.24
T_6	3.478	190	3.233	283	3.933	310	3.548	261	1.36

The rainfed treatment performed best in respect of water productivity. This was due to the fact that this treatment used 42% water over that produced the highest yield at Jamalpur. Even it produced about 60% grain of the highest yielder. This indicates that no irrigated treatment used some residual soil moisture and rainfall occurred during the three cropping seasons. This provided a little scope for the plants to overcome an acute shortage of water. As a result, a considerable yield of

2.186 t/ha was produced by the treatment giving the highest water productivity of 1.92 kg/m^3. However, this output is not considerable in the context of increasing food production and land use productivity. The model performed better than the BARI traditional irrigation practice in respect of both yield and water use in Barind area, Rajshahi.

Table 8. Yield, total water use and water productivity of different treatments in Rajshahi site.

Treatment	Year 2005-2006		Year 2006-2007		Year 2007-2008		Average yield (t/ha)	Average TWU (mm)	Water productivity (kg/m^3)
	Yield (t/ha)	TWU (mm)	Yield (t/ha)	TWU (mm)	Yield (t/ha)	TWU (mm)			
T_1	1.599	91	1.37	91	2.389	112	1.786	98	1.82
T_2	3.449	256	2.78	266	3.803	288	3.344	270	1.24
T_3	3.651	244	3.31	311	3.833	312	3.598	289	1.25
T_4	3.649	209	2.86	265	4.153	276	3.554	250	1.42
T_5	3.549	244	3.15	260	3.930	303	3.543	269	1.32
T_6	3.909	209	2.85	263	3.861	287	3.540	253	1.38

A comparative result on grain yield and total water use at two locations are shown in Table 9.

Table 9. Comparative average yield and total water use of two locations (Three years' average).

Treatment	Jamalpur		Rajshahi	
	Yield (t/ha)	Total water use (mm)	Yield (t/ha)	Total water use (mm)
T_1	2.186	114	1.786	98
T_2	**3.642**	271	3.344	270
T_3	3.544	295	**3.598**	289
T_4	3.487	256	3.554	250
T_5	3.469	280	3.543	269
T_6	3.548	261	3.540	253

Highest average grain yield of 3.642 t/ha was obtained using less water (271 mm) at Jamalpur site. On the other hand, highest average grain yield of 3.598 t/ha was obtained from a model based treatment T_3 at Barind, Rajshahi site. However, treatment T_3 used the maximum water (295 mm and 289 mm, respectively) at both the sites.

Conclusion

From the results, it is evident that DRAS model performs well in the drought prone locations as the plants can utilize the irrigated water in a better way. BARI recommended irrigation practice seems good for locations having adequate water holding capacity of soils and higher rainfall situation. However, the difference between other two systems in respect of yield being very low, DRAS model based irrigation scheduling may be advocated to wheat growing farmers of the country for its better water use capacity and water productivity

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