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Assessment of the Effect of Climate Change on Boro Rice Yield and Yield Gap using DSSAT Model

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ABSTRACT

The actual yield of different Boro varieties is often much lower than the potential yield (ie, yield without any water and fertilizer stress), commonly referred to as yield gap. We investigates the possible impact of climate change on Boro rice yield and yield gap by estimating the potential yield and yield under commonly employed crop management practices (ie, irrigation and fertilizer application) for the years 2030, 2050 and 2070 using the DSSAT modeling system. The model has been used for predicting yields of the BR3 and BR14 Boro rice varieties for 12 major rice growing locations in Bangladesh. Available data on soil and hydrologic characteristics of these locations, and typical crop management practice for Boro rice have been used in the simulations. The weather data required for the model (daily maximum and minimum temperatures, daily solar radiation and daily precipitation) were generated for the selected years and for the selected locations using the regional climate model PRECIS. The crop model predicted significantly lower yield of the Boro rice varieties and increasing trend of rice yield gap in the future under the present crop management practice, suggesting that among other measures, the currently used agricultural practices would have to be changed for offsetting the adverse effect of climate change on Boro yield. The model predicted that under currently employed practice, the average yield gap (average of 12 selected locations) for BR3 rice variety would be 30, 43 and 52% for the years 2030, 2050 and 2070 respectively. The corresponding yield gaps for BR14 rice variety were predicted to be 37, 49 and 58%. Increasing atmospheric carbon-dioxide concentrations have been predicted to increase rice yield gap in the future. Rice yield and yield gap have also been found to be sensitive to transplanting date. Such yield reductions under changed climatic conditions could significantly affect food production and food security in Bangladesh. Among other initiatives, adaptation of proper crop management practices could reduce the severity of such adverse impacts. It is also necessary to develop high temperature-resistant rice varieties and modify management practices to offset the adverse effects of climate change.

Keywords: Bangladesh, climate change, Boro rice, rice yield, yield gap, DSSAT model

INTRODUCTION

Most existing rice varieties, particularly modern varieties and hybrids, have a potential yield that is higher than the actual yield commonly achieved by farmers, and there is considerable variation in the actual yield levels achieved, even under similar production systems. Potential yield is commonly referred to as yield under no nitrogen (fertilizer) and water stress. Actual yields of irrigated rice in Bangladesh are only about 4 to 6 tones per ha, while the potential yield of modern rice varieties could be as high as 10 to 11 tones per ha. Yield differences among farmers in the same area are frequent because of the different levels of crop management and the diversity of environments in the area (FAO, 2004). The expert consultation on yield gap and productivity decline in rice production, convened by FAO in Rome in 2000, recognized that there is a sizeable yield gap between attainable and farm-level yields across the ecologies, the regions, within ecologies and the crop seasons in many rice growing countries. The yield gap between attainable and farm-level yields ranges from 10 to 60 percent. This yield gap could potentially increase in the future under adverse climatic conditions due to climate change,

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especially if current agricultural practices are continued.

A number of simulation studies have been carried out to assess impacts of climate change and variability on rice productivity in Bangladesh (eg, Basak *et al,* 2009; Mahmood *et al,* 2003; Mahmood, 1998; Karim *et al,* 1996) and some of these studies have predicted lower rice yield under different climate change scenarios. Basak (2009) and Basak *et al.* (2010) reported predicted significant reduction in yield of some varieties of Boro rice due to climate change; yield reductions of over 20 and 50% have been predicted for the years 2050 and 2070 respectively. This study presents an assessment of the Boro rice yield gap (ie, difference between potential yield and yield under presently employed agricultural practice) under future climate scenarios.

In this study, future climate scenarios have been depicted using the climate model named Providing Regional Climates for Impact Studies (PRECIS). The weather data requirement for DSSAT (Decision Support System for Agrotechnology Transfer, version 4) model include daily maximum and minimum air temperatures, daily precipitation and daily solar radiation, all of which could affect rice yield significantly. Therefore, future climate scenarios, including daily maximum and minimum temperatures, precipitation and solar radiation, for selected locations of Bangladesh have been generated and used for predicting yield gaps of Boro rice. The yield of two Boro varieties (BR3 and BR14) have been simulated in the present study for the years 2008, 2030, 2050 and 2070, using the DSSAT modeling system.

MATERIALS AND METHODS

Selection of simulation locations

The yield (both potential yield and rice yield under an assumed crop management practice) of two Boro rice varieties BR3 and BR14 for the years 2008, 2030, 2050 and 2070 have been simulated for 12 districts of Bangladesh, which were selected from among the major rice growing areas in different regions of Bangladesh. Among them, Rajshahi, Bogra and Dinajpur were selected from northwestern region; Mymensingh and Tangail were selected from central region; Jessore and Satkhira from southwestern region; Barisal and Madaripur from southern region; Chandpur and Comilla from southeastern region; and Sylhet district from eastern region. In addition, the yields (potential and actual yield) of the rice varieties under varying transplanting date were also assessed.

Crop model

The DSSAT modeling system is an advanced physiologically based rice crop growth simulation model and has been widely applied to understand the relationship between rice and its environment. The model estimates yield of irrigated and non-irrigated rice, determine duration of growth stages, dry matter production and portioning, root system dynamics, effect of soil water and soil nitrogen contents on photosynthesis, carbon balance and water balance. Ritchie *et al.* (1987) and Hoogenboom *et al.* (2003) have provided a detailed description of the model. In the present study, the Introductory Crop Simulation (ICSim) of DSSAT modeling system has been used for all simulations.

Selection of rice variety

The DSSAT model is variety-specific (eg, BR3 Boro) and is able to predict rice yield and rice plant response to various environmental conditions. In predicting crop growth and yield, the model takes into consideration of weather, crop management, genetics, and soil water, C and N. The model uses a detailed set of crop specific genetic coefficients, which allows the model to respond to diverse weather and management conditions. Therefore, in order to get reliable results from model simulations, it is necessary to have the appropriate genetic coefficients for the selected cultivars. The two Boro rice varieties BR3 and BR14 have been selected in the present study because genetic coefficients for these varieties are available in the DSSAT modeling system. Although these varieties are not widely used at present, the effects of climate change and variability on these varieties provide insights into possible impact of climate change on Boro rice yield gap.

Soil and crop management input

The DSSAT model requires a detailed set of input data on soil and hydrologic characteristics (ie, pedological and hydrological data), and crop management. Input data related to soil characteristics include soil texture, number of layers in soil profile, soil layer depth, pH of soil for each depth, clay, silt and sand contents, organic matter and cation exchange capacity etc. Required data on soil and hydrologic characteristics for the 12 selected locations (districts) were collected from Bangladesh Rice Research Institute (BRRI, Gazipur; BARC, 2005; Karim *et al,* 1998) and Soil Resources Development Institute (SRDI, Dhaka). As an example, Table 1 presents the soil profile data used in the model for the the Old Meghna Estuarine Floodplain (ie, Agro-ecological zone, AEZ-19) covering Kishoregani, Habiganj, Brahmanbaria, Comilla, Chandpur, Feni, Noakhali, Laksmipur, Narsingdi, Narayanganj, Dhaka, Shariatpur, Modaripur, Gopalganj and Barisal districts.

The crop management data (ie, agronomic data) required by the model include planting date, planting density, row spacing, planting depth, irrigation amount and frequency, fertilizer application dates and amounts. Table 2 shows the major crop management input data used in all model simulations in the present study. It represents typical practices (BRRI, 2006 and Rashid, 2008) in Bangladesh. Using these inputs, the average (of 12 locations) yields of BR3 and BR14 for 2008, estimated by the model, were about 5500 kg ha^{-1} and 4050 kg ha^{-1} respectively. These values are close to the reported yields of these varieties (BRRI, 2007). These crop management inputs were subsequently used in all model simulations under the predicted weather scenarios for 2008, 2030, 2050 and 2070. It should be noted that the DSSAT model does not count the water required for preparation of land before transplanting (which usually varies from 200 to 300 mm, depending on soil and weather condition).

Weather data

In this study, a regional climate model named Providing Regional Climate for Impacts Studies (PRECIS) was used to generate daily weather data needed for running the DSSAT model. The special report on emission scenarios (SRES) A2 of ECHAM4 has been used as PRECIS input. In this study PRECIS was run with 50-km horizontal resolution for the present climate (2008) using baseline lateral boundary conditions (LBCs). The model domain was selected 65-103°E and 6-35°N to cover Bangladesh and its surroundings. In the next step PRECIS run was completed for 2030, 2050 and 2070 using ECHAM 4 SRES A2 as the model input. The PRECIS outputs that were used in the DSSAT model include daily maximum temperature (T_{max}), daily minimum temperature (T_{min}), daily incoming solar radiation (Srad), and daily precipitation. These parameters were extracted at 12 locations mentioned in subsection named Selection of Simulation Locations.

Table 1. Soil profile data for Old Meghna Estuarine Floodplain (AEZ-19).

Depth bottom (cm)	Clay (%)	Silt (%)	Stones (%)	Organic carbon (%)	pH in water	Cation exchange capacity meq/100 gm	Total nitrogen (%)
5	13	38	0	1.51	5.6	11.3	0.14
15	13	38	0	1.51	5.6	11.3	0.14
30	13	38	0	1.43	5.6	11.3	0.13
45	13	38	0	1.22	5.6	11.3	0.11

Soil texture: Silt loam.

Table 2. Crop management data used in the model simulations.

Parameter	Input data
Planting method	Transplant
Transplanting date	1, 5, 15 and 25 January
Planting distribution	Hill
Plant population at seedling	35 plants per m^2
Plant population at emergence	33 plants per m^2
Row spacing	20 cm
Planting depth	3 cm
Transplanting age	35 days
Plant per hill	2
Fertilizer (N) application	
18-day-after transplanting	30 kg ha^{-1}
38-day-after transplanting	70 kg ha^{-1}
56-day-after transplanting	30 kg ha^{-1}
Application of irrigation	855 mm in 14 applications

RESULTS AND DISCUSSIONS

Impact of climate change on rice yield and yield gap

Tables 3 and 4 show predicted rice yield (potential and actual yield) and yield gaps of BR3 and BR14 Boro rice varieties respectively at 12 locations of Bangladesh in 2030, 2050 and 2070. These predictions have been made using a fixed concentration of atmospheric CO_2 of 379 ppm (the value reported for 2005 in the fourth assessment report of IPCC) and for planting date of 15 January. In general, Tables 3 and 4 show significant reductions in predicted rice yield in the future due to predicted changes in climatic condition. These tables also show significant change in rice yield gaps in the future due to predicted changes in climatic condition and the predicted yield gaps increased significantly with time from 2030 to 2070 (Fig. 5). Predicted average rice yield gaps of BR3 variety for the 12 selected locations are about 30% for 2030, 43% for 2050 and 52% for 2070. The corresponding changes for BR14 variety are about 37, 49 and 58% for 2030, 2050 and 2070 respectively. Some regional variation could also be observed in the predictions, with somewhat higher rice yield gaps predicted for northwestern, central, southern and southwestern regions. Figures 1 and 2 show predicted average yield gaps of BR3 and BR14 rice varieties for 2030, 2050 and 2070.

Increasing atmospheric CO_2 concentration is likely to have some positive effect on rice yield. If

Table 3. Predicted yield and potential yield (kg ha^{-1}) for BR3 rice at 12 selected locations in Bangladesh. (fixed Carbon dioxide concentration 379 ppm)

Station name	Potential yield			Rice yield			% change in rice yield gap		
	2030	2050	2070	2030	2050	2070	2030	2050	2070
Rajshahi	7118	7073	3440	4083	3265	1785	42.6	53.8	48.1
Bogra	6650	7320	4144	5119	4070	2036	23.0	44.4	50.9
Dinajpur	7535	8058	5643	4824	4364	2692	36.0	45.8	52.3
Mymensingh	6418	7633	5529	5275	4455	2739	17.8	41.6	50.5
Tangail	6749	7201	3799	5160	3874	1938	23.5	46.2	49.0
Jessore	7276	6946	4103	4432	4583	1997	39.1	34.0	51.3
Satkhira	7305	7106	4403	4364	3603	2066	40.3	49.3	53.1
Barisal	7067	7217	6649	4006	3972	2091	43.3	44.9	68.6
Madaripur	7126	7298	5154	4017	3647	2186	43.6	50.0	57.6
Chandpur	7092	7253	5684	5455	4039	2772	23.1	44.3	51.2
Comilla	7418	7578	5804	5987	4456	3075	19.3	41.2	47.0
Sylhet	5787	6897	6853	5117	5750	3595	11.6	16.6	47.5

Table 4. Predicted yield and potential yield (kg ha^{-1}) for BR14 rice at 12 selected locations in Bangladesh. (fixed Carbon dioxide concentration 379 ppm)

Station name	Potential yield			Rice yield			% change in rice yield gap		
	2030	2050	2070	2030	2050	2070	2030	2050	2070
Rajshahi	5640	5542	2607	2771	2392	1148	50.9	56.8	56.0
Bogra	5399	5703	3062	3668	2637	1398	32.1	53.8	54.3
Dinajpur	6021	6281	4014	3374	3023	1656	44.0	51.9	58.7
Mymensingh	5074	5936	4023	3790	3186	1873	25.3	46.3	53.4
Tangail	5382	5641	2937	3883	2565	1297	27.9	54.5	55.8
Jessore	5563	5465	3148	3160	3153	1305	43.2	42.3	58.5
Satkhira	5578	5513	3332	3171	2434	1377	43.2	55.9	58.7
Barisal	5475	5713	4952	2889	2705	1457	47.2	52.7	70.6
Madaripur	5471	5786	3873	2606	2578	1491	52.4	55.4	61.5
Chandpur	5500	5734	4402	3981	2801	1842	27.6	51.2	58.2
Comilla	5752	5791	4494	4368	3063	1978	24.1	47.1	56.0
Sylhet	4843	5582	5282	3764	4240	2378	22.3	24.0	55.0

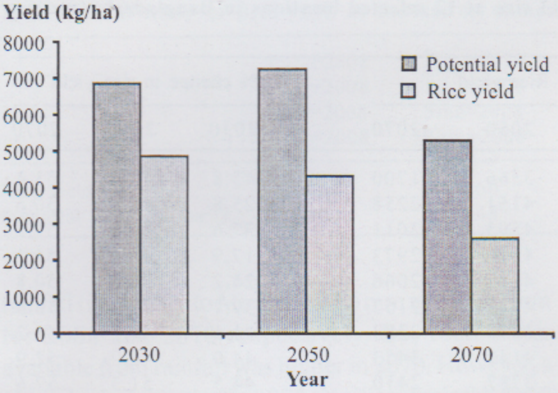

Fig. 1. Predicted average yield (average of 12 locations) and potential yield of BR3 Boro rice under fixed atmospheric CO_2 concentration.

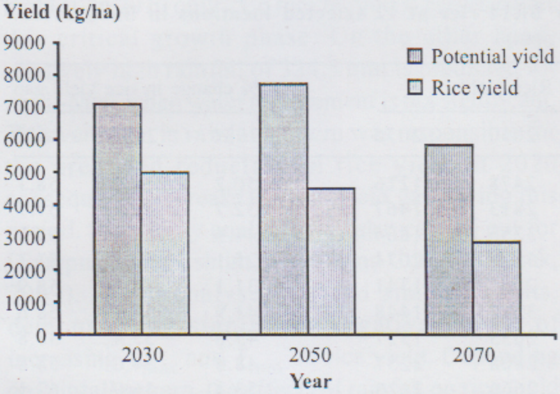

Fig. 2. Predicted average yield (average of 12 locations) and potential yield of BR3 Boro rice under different atmospheric CO_2 concentration.

rate of change of atmospheric CO_2 concentration from 1994 (358 ppm) to 2005 (379 ppm) (ie, about 1.9 ppm per year) is used to set the CO_2 concentrations in 2030 (at 427 ppm), 2050 (at 465 ppm), and 2070 (at 503 ppm), then the model predicts slightly higher yield gaps (compared to predicted yield gaps at 379 ppm CO_2). When the CO_2 levels were increased to 427, 465 and 503 ppm in 2030, 2050 and 2070, respectively, predicted rice yield gaps increased by 0.06 to 7.3% for BR3 rice and 0.01 to 4.6% for BR14 rice at different locations (Tables 5 and 6). Thus, while increasing CO_2 concentrations are predicted to increase yield to some extent, thus slightly offsetting the adverse effects of other climatic parameters on rice yield (Basak, 2009; Basak *et al*, 2010), it has been predicted to increase the yield gap of Boro rice even more. Figures 3 and 4 show effect of increasing CO_2 on yields of BR3 and BR14 rice varieties for 2030, 2050 and 2070. It should be noted that the predicted increase of potential yield for 2050 is higher than 2030 for some selected locations in Bangladesh, which could also be explained by the variation in predicted temperatures, rainfall and solar radiation at these locations (Basak, 2009).

Sensitivity of rice yield and yield gap to climatic parameters

The climatic parameters used in the model are daily maximum temperature (T_{max}), daily minimum temperature (T_{min}), daily solar radiation (Srad) and daily precipitation (Rain). In order to assess relative importance of these parameters on predicted rice yield gap, Basak (2009) carried out sensitivity analysis by predicting yield of BR3 and BR14 rice varieties for a number of locations using predicted climatic parameters for 2008 and 2070, changing one parameter at a time; atmospheric CO_2 concentration was kept fixed at 379 ppm. Table 7 shows the results of the sensitivity analysis for BR3 rice variety in Barisal.

Table 7 shows that T_{max} has the most significant negative impact on rice yield, followed by rainfall, and T_{min}; predicted solar radiation, on the other hand, has some positive effect on yield. Analysis of predicted temperatures showed that average T_{max} during January-May (ie, rice growing season) for 2008 and 2070 were 30.73 °C and 35.11 C respectively; this significant increase in T_{max} resulted in reduction of rice yield of BR3 by about 31% and for potential yield, it was 21%. Average T_{min} during this period for 2008 and 2070 were 21.52 °C and 25.22 °C, and the increase in T_{min} caused a reduction of 17% in the predicted rice yield and 10% for the potential yield. Average solar radiation in 2008 and 2070 are 15.37 and 16.71 MJ/m^2/day respectively and this increase in solar radiation actually increased the predicted rice yield by about 11% and 18% for potential yield. Like BR3, similar yield reductions were also predicted for BR14 rice, both actual and potential yields.

Table 7 shows significant negative effect of rainfall on BR3 rice yield. Since a fixed irrigation schedule (855 mm in 14 applications) was used in all model simulations, change in rainfall affected predicted yield by changing availability of water. Analysis of predicted rainfall data showed total

Table 5. Predicted yield and potential yield (kg ha^{-1}) for BR3 rice at 12 selected locations in Bangladesh. (various carbon dioxide concentration 427 ppm, 465 ppm, 503 ppm).

Station name	Potential yield			Rice yield			% change in rice yield gap		
	2030	2050	2070	2030	2050	2070	2030	2050	2070
Rajshahi	7370	7544	3814	4141	3366	1700	43.8	55.4	55.4
Bogra	6891	7809	4574	5115	4151	2258	25.8	46.8	50.6
Dinajpur	7804	8586	6207	4868	4593	3011	37.6	46.5	51.5
Mymensingh	6647	8135	6080	5459	4590	2973	17.9	43.6	51.1
Tangail	6993	7680	4196	5301	4087	2066	24.2	46.8	50.8
Jessore	7543	7406	4538	4546	4717	2157	39.7	36.3	52.5
Satkhira	7571	7582	4875	4463	3815	2283	41.1	49.7	53.2
Barisal	7317	7659	7332	4097	4140	3453	44.0	46.0	52.9
Madaripur	7380	7783	5690	4099	3787	2410	44.5	51.3	57.6
Chandpur	7346	7735	6261	5660	4225	3118	23.0	45.4	50.2
Comilla	7679	8079	6384	6207	4468	3309	19.2	44.7	48.2
Sylhet	5994	7350	7521	5301	6063	3920	11.6	17.5	47.9

Table 6. Predicted yield and potential yield (kg ha^{-1}) for BR14 rice at 12 selected locations in Bangladesh. (various carbon dioxide concentration, 427 ppm, 465 ppm, 503 ppm)

Station name	Potential yield			Rice yield			% change in rice yield gap		
	2030	2050	2070	2030	2050	2070	2030	2050	2070
Rajshahi	5852	5930	2902	2912	2478	1216	50.2	58.2	58.1
Bogra	5604	6104	3472	3772	2813	1467	32.7	53.9	57.7
Dinajpur	6246	6713	4432	3459	3255	1864	44.6	51.5	57.9
Mymensingh	5263	6345	4442	3940	3189	2074	25.1	49.7	53.3
Tangail	5585	6036	3259	3847	2744	1341	31.1	54.5	58.9
Jessore	5772	5845	3495	3179	3287	1448	41.9	43.8	58.6
Satkhira	5786	5898	3702	3250	2633	1527	43.8	55.4	58.8
Barisal	5675	6108	5481	2952	2808	2257	48.0	54.0	58.8
Madaripur	5673	6186	4292	2662	2666	1626	53.1	56.9	62.1
Chandpur	5705	6129	4868	4151	2975	2027	27.2	51.5	58.4
Comilla	5962	6190	4963	4256	3053	2249	28.6	50.7	54.7
Sylhet	5025	5967	5820	3915	4518	2603	22.1	24.3	55.3

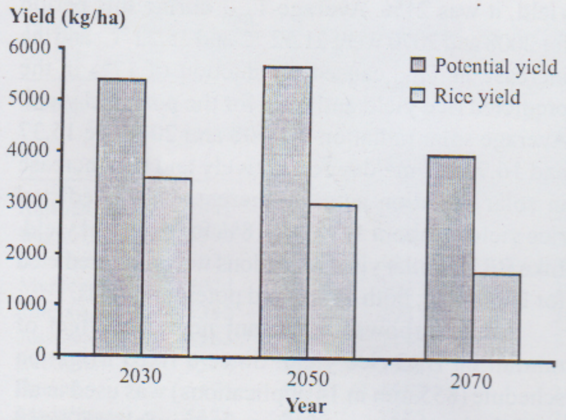

Fig. 3. Predicted average yield gap (average of 12 locations) of BR14 Boro rice under fixed atmospheric CO_2 concentration.

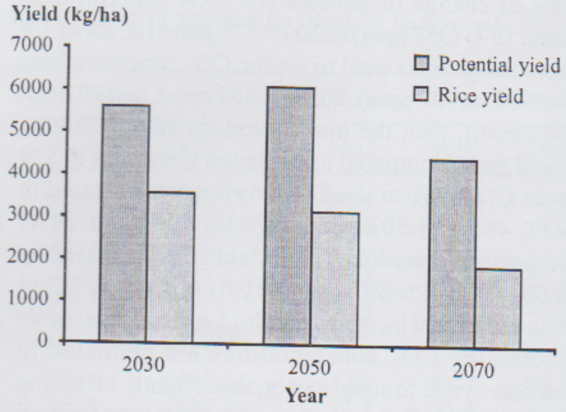

Fig. 4. Predicted average yield gap (average of 12 locations) of BR14 Boro rice under different atmospheric CO_2 concentration.

Table 7. Sensitivity of BR3 yield at Barisal on climatic parameters.

	T_{max}=2008 T_{min}=2008 Srad=2008 Rain=2008	T_{max}=2070 T_{min}=2008 Srad=2008 Rain=2008	T_{max}=2008 T_{min}=2070 Srad=2008 Rain=2008	T_{max}=2008 T_{min}=2008 Srad=2070 Rain=2008	T_{max}=2008 T_{min}=2008 Srad=2008 Rain=2070	T_{max}=2070 T_{min}=2070 Srad=2070 Rain=2070
Rice yield (kg ha^{-1})	6043	4160	5039	6714	4354	2091
Potential yield (kg ha^{-1})	7431	5848	6670	8746	7341	6649

rainfall (in January to May) of 144.6 mm and 356.1 mm for 2008 and 2070 respectively. So, total water available from rainfall was higher in 2070. However, a closer look shows that in 2008 significant rainfall (96.3 mm) is predicted in January to March, which represent the vegetative phase and a part of reproductive phase of rice plant and in which water requirement is the highest. In 2070 only 21.6 mm rainfall is predicted for this critical growth phase. On the other hand, relatively high rainfall of 334.5 mm is predicted for April-May, when water requirement is not significant. This variation in rainfall pattern was responsible for the predicted reduction in rice yield in 2070 consequently increase the rice yield gap during this period. Sensitivity analysis was also carried out for Dinajpur, Mymensingh, Jessore and Comilla (Basak, 2009). These analyses yielded similar results, demonstrating significant negative impact of increasing T_{max} and T_{min} on rice yield. Depending on rainfall pattern, the effects of rainfall on rice yield at these locations were different (Basak, 2009).

As noted earlier and shown in Fig. 5, the predicted rice yield gaps increased with time. This was found to be primarily due to significant increases in T_{max} and T_{min}. For example, in Barisal, average T_{max} in January-May (ie, rice growing season) for 2030 and 2070 are 29.79 °C and 35.11 °C respectively, average T_{min} during this period for 2030 and 2070 are 20.28 °C and 25.22 °C. Predicted rice yield gaps for BR3 in Barisal for 2030 and 2070 are 43.3% and 68.6%, respectively (Fig. 5).

Effect of planting date on rice yield and yield gap

Basak (2009) and Basak *et al.* (2010) reported significant reduction of Boro rice yield as transplanting date is delayed beyond 15 January. BRRI (2011) has recommended 15 December to 1 January for transplanting date of BR3 varieties and 23 December to 7 January for BR14. In this study, the effect of planting date on rice yield gap has been assessed by setting the planting date on 1, 5, 15 and 25 January and simulating yield for each case under fixed CO_2 concentration. In general, the predictions indicate significant increase in rice yield gaps for delayed planting, especially beyond 15 January. For planting dates of 15 and 25 January, the average rice yield gaps in BR3 variety (compared to yield for planting date of 1 January) for the six regions in Bangladesh are 28 and 38% respectively for 2030; the corresponding change of rice yield gaps for BR14 are 35 and 42% respectively for 2030. The effect appears to be more pronounced for 2050 and 2070. For transplanting dates beyond 15 January, average yield gaps for the six regions increased more than 40% in 2050 and 50% in 2070. Also the predicted yield gaps for both rice varieties appear to be more pronounced for locations in northwestern and southern regions. For example, for planting dates of 15 and 25 January, the average rice yield gaps in BR3 yield (compared to yield for planting date of 1 January) for the three locations in northwestern region are 48 and 50% respectively for 2050; and 51 and 52% respectively for 2070; the corresponding yield

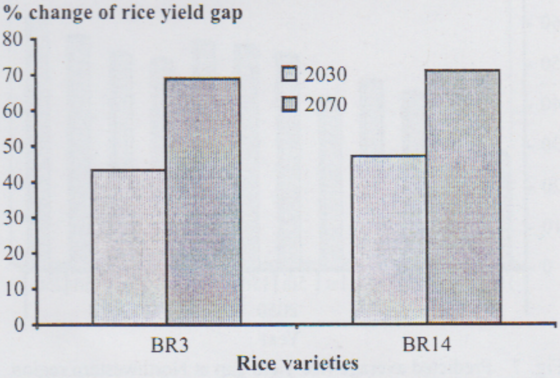

Fig. 5. Predicted rice yield gap of BR3 and BR14 Boro rice for Barisal in 2030 and 2070.

reductions for BR14 are 54 and 55% respectively for the year 2050; and 57 and 62% respectively for 2070 (Figs. 6 and 7). It may be noted that Mahmood *et al.* (2003) reported significant reduction in yield of Aman (wet season rice) as planting is delayed beyond 1 June Thus, the climate change could not only cause significant increase in yield gap of Boro rice, but could also make yield and yield gap more sensitive to planting time.

CONCLUSIONS

Although currently the BR3 and BR14 Boro rice varieties are not widely cultivated in Bangladesh, the model simulations carried out in this study provide useful insight into the possible effects of climate change on rice yield and yield gap. The growth and yield of crops are directly related to the rate of photosynthesis and phenology and their response to temperature, solar radiation and rainfall. Optimum temperatures for maximum photosynthesis range from 25 to 30 °C for rice under the climatic conditions of Bangladesh. Increased temperatures during the growing season cause grain sterility. Very high temperatures, sometimes exceeding 35 °C, have been predicted, especially in 2050 and 2070, due to climate change. Although there are significant uncertainties in the predicted climate parameters, the crop model simulation results suggest that if climate change causes significant increase in temperatures, this may in turn could cause significant reduction in rice yield; if the current crop management practices (irrigation and fertilizer application) are continued, this could significantly increase rice yield gap. Sensitivity analysis indicates that rice yield is also sensitive to CO_2 levels and solar radiation. The model simulations also suggest that changes in rainfall pattern may also adversely affect rice yield and yield gap. Simulation results also suggest that planting dates could significantly affect rice yield and yield gap, and this effect could become more pronounced in the future. Rice yield gap could be significantly higher if the transplanting date is delayed beyond 15 January. In order to assess the effect of climate change on the rice varieties currently being grown in Bangladesh, it is necessary to determine their genetic coefficients through carefully controlled experiments. It is also necessary to develop high temperature-resistant rice varieties and modify crop management practices to offset the adverse effects of climate change. Modeling tools, such as the DSSAT modeling system, could be very useful in assessing possible impacts of climate change and management practices on rice yield. The predicted values of temperature and rainfall used in the present study have not been calibrated on daily scale. Uncertainty in assessing possible impacts of climate change may also be reduced using high resolution climate model outputs with ensembles and calibrated outputs.

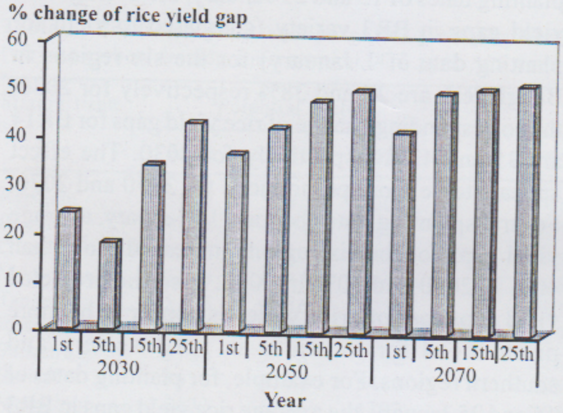

Fig. 6. Predicted average rice yield gap at Northwestern region (average of three locations) of BR3 under different planting dates of January.

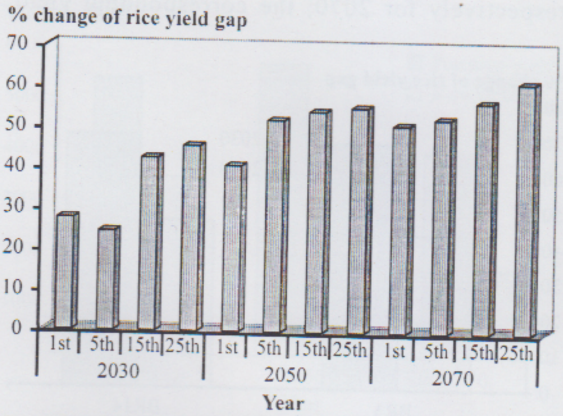

Fig. 7. Predicted average rice yield gap at Northwestern region (average of three locations) of BR14 under different planting dates of January.

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