IMPACT OF HIGH END EMISSION ON THE PRODUCTION OF BORO RICE IN BANGLADESH USING DSSAT 4.5

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ABSTRACT
Impact of high end emission on production of BORO rice in Bangladesh has been evaluated using the DSSAT 4.5 crop modeling system. It was calibrated using BR3 variety for the years 2001-2005 and validated for 2006-2010 incorporating BBS data with statistical parameters RMSE and NSE. Impact of future climate is analyzed for the years 2020's (2016-2035), 2050's (2036-2055) and 2090's (2081-2099) with baseline years 1991-2010 using 7 bias corrected ensembles regional climate models (RCM's) for 64 districts divided in 23 regions. The soil profile data was extracted from WISE 1.1 soil database. The results show that, the yield is negative everywhere, reaching over 20% decrease in some regions. The maximum temperature rise exceeds 1.5°C in 2020's and 4°C in 2090's whereas the minimum temperature rises up to 5°C in 2090's. This rise in daily temperature over the growing period of BORO rice indicates the adverse impact of temperature on crops.

Keywords: BORO Rice; RCM; Climate change; DSSAT 4.5

INTRODUCTION
Agriculture contributes to 35% of the GDP and 70% of the labor force in Bangladesh. The problem of huge and increasing demands for food and of agricultural land and water resources depletion make it worse (Ahmed et al., 2000). Bangladesh has to emphasize more on the staple food rice and will require more than 55.0 million tons of rice to feed its people by the year 2050(Basak, 2010). The impacts of climate change on food production very important for Bangladesh. BORO rice is the leading rice producer variety of Bangladesh (BRRI, 2006). However, climate change is the major threat towards rice production. It is very important to evaluate the effect of climate change on BORO production. A number of simulation studies have been carried out to assess impacts of climate change and variability on rice productivity in Bangladesh using the CERES-Rice model of DSSAT. (Mahmood et al., 2003; Mahmood, 1998; Karim et al., 1996). For instance, Basak(2010) has carried out simulations of 12 representative regions from various zones of the country using the regional climate model PRECIS. However, this study covers simulation over all the 23 zones of the country that contains all 64 districts using seven numbers of bias corrected ensembles of regional climate models which has taken high end emission into account while projecting the future climate data.

METHODOLOGY

Study area
This study was done on Bangladesh (20°34″ North Latitude to 26°38″ North Latitude and from 88°01″ East Longitude to 92°41″ East Longitude) which that encompass almost 0.15 million Km^2 territory. Bangladesh is the largest delta of the world as 80% of the land is formed by the floodplains of the GBM

basin (Ganges, Brahmaputra & Meghna) making it a fertile land for rice production. The country experiences huge rainfall during Monsoon. However, some flash floods prior to the monsoon season also occur. This tropical country has annual average rainfall of 1600 mm and a temperature ranging from 8° to 38°during the growth season of Boro rice (Nov-April) over the last 30 years (1981-2010).

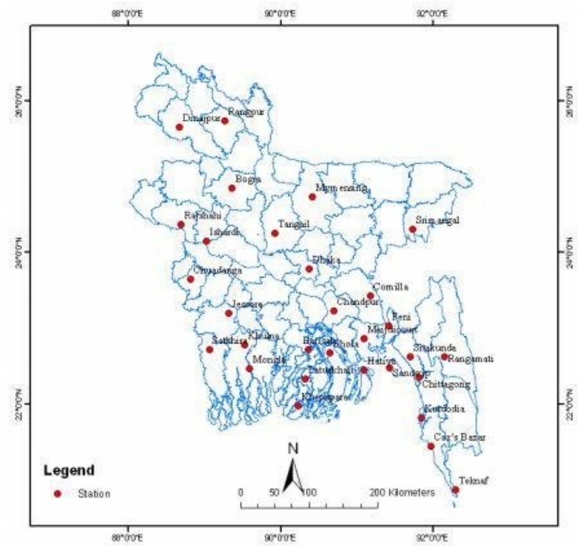

Fig. 1: Thirty five ground base measuring stations of Bangladesh Meteorological Department. Source (Islam 2008)

Selection of Crop Model

Among the various crop modeling software like Crop-wat, DSSAT, PCSE etc. we have chosen DSSAT 4.5 to calibrate and project the crop yields. The CERES-Rice model of the DSSAT modeling system is an advanced physiologically based rice crop growth simulation model and has been widely applied to understanding 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.

Selection of Rice Variety

The CERES-Rice model is variety-specific and is able to predict rice yield and rice plant response to various environmental conditions. The model takes into effect 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. The BORO rice variety BR3 has been selected as the genetic coefficients of BR3 is available in the model.

Table 1: Some important information about BR3 variety of Boro rice

Real Name	Biplob Height
95 cm Duration of growth	170 days Grain quality
CoarseYield (Kg/hectares)	6500
Developed on	1975
Developed by	Bangladesh Rice Research Institute (BRRI)

Integrating field data in DSSAT

The DSSAT software team has recently done experiments on 17 soil stations across Bangladesh. The soil station data has been stored in WISE 1.1 database. Once a region is selected from the global map, it enables the user to access the soil station data. This set of data is simply copied and pasted on the soil.sol file. Thus the soil stations can easily be integrated in DSSAT.

Weather data

In this study, the historic weather data was taken from 35 stations of Bangladesh Meteorological Department (BMD). The weather data contains daily rainfall (mm), maximum and minimum temperature (°C) and daily solar hours. Rainfall and temperatures are used directly in DSSAT. However, the weather manager of DSSAT itself converts solar hours into solar radiation. As simulations were carried out over 23 zones, the data of the nearest station of the corresponding district was taken. Figure 1 indicates the location of the meteorological stations of BMD. For calibrating the model, data of the years from 2001-2005 was taken and 2006-2010 was taken for validation.

Climatic Data

The future data was collected from 7 bias corrected ensembles with RCP 8.5 scenario of regional climate models RCM's under 4 GCM's. The baseline period was 30 years (1991-2010) and the projection was made for 2020's (2016-2035), 2050's (2046-2065) and 2090's (2080-2099). Table 2 describes the details of the ensembles.

Table 2: Details of the bias corrected ensembles of regional climate models

Institute	**GCM**	**RCM**	**Driving Ensemble Member**	**Res.**	**RCP**
SMHI	CNRM-CERFACS-CNRM-CM5	RCA4	r 1i1p1	0.5°	8.5
SMHI	ICHEC-EC-EARTH	RCA4	r 1i1p1	0.5°	8.5
MPI- CSC	MPI-M-MPI-ESM-LR	REMO2009	r 1i1p1	0.5°	8.5
SMHI	MPI-M-MPI-ESM-LR	RCA4	r 1i1p1	0.5°	8.5
SMHI	NOAA-GFDL-GFDL-ESM2M	RCA4	r 1i1p1	0.5°	8.5
SMHI	IPSL-CM5A-MR	RCA4	r 1i1p1	0.5°	8.5
SMHI	MIROC-MIROC5	RCA4	r 1i1p1	0.5°	8.5

Crop Management

The crop management includes planting details, transplanted date, irrigation and fertilizer management, tillage, harvest and chemical applications. The date of transplant, the date of harvest, the amount ofirrigation and fertilizer applications has been kept the same to a default set value according to the guidelines of BRRI.

Calibration and Validation:

The model was calibrated to find the genetic coefficients for BR3 variety of Boro rice. Statistical parameters root mean square error (RMSE) was used for the calibration. Value of RMSE was ranging from 100- 300 depending on the soil profile and climatic scenario of the region. Table 3 shows the default values of the genetic coefficients and the calibrated value of these parameters in some important locations (divisions).

Table 3: Values of the genetic coefficients in some important locations (divisions)

Region	P1	P2R	P5	P20	G1	G2	G3	G4	RMSE (Calibration)	RMSE (Validation)
Default value	650	90	400	13	0.65	0.25	1	1	-	-
Dhaka	647	93	415	12.9	67	0.26	1	1	260	125
Chittagong	645	87	395	12.9	62	0.25	1	1	312	213
Rajshahi	647	93	415	12.9	67	0.26	1	1	317	106
Barisal	648	90	400	13	67	0.25	1	1	192	141
Khulna	648	90	400	13	67	0.25	1	1	211	139
Sylhet	650	90	400	13	67	0.25	1	1	169	140
Rangpur	650	90	400	13	65	0.25	1	1	315	154

RESULTS AND DISCUSSIONS

It is observed that, most of the regions experience negative yield of BORO rice, reaching over 20% decrease in some regions (Figure. 2). The maximum temperature rise exceeds 1.5°C in 2030's and 4°C in 2090's whereas the minimum temperature rises up to 5°C in 2090's. (Figure. 3) This rise in daily temperature over the growing period of BORO rice indicates the adverse impact of temperature on crops. The results show a spatial distribution of the change of rice yield. As we see figure 4, for mid future (2050's), the North East zone encounters the minimum reduction in yield (2-6%). On the contrary, the southern zone is the most danger prone region experiencing a 14% to above 20% decrease in yields. Over the near and far future, the western zone of Bangladesh remains moderately affected by reduction of rice yield from 8% to 12%. However, the condition of the central zone is also affected in the far future which indicates how severe the impact of climate change is going to endanger the whole country in future.

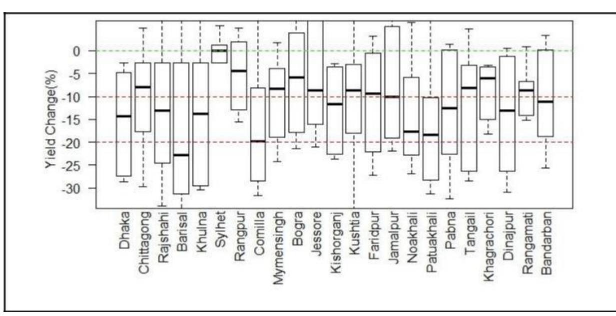

Fig.2: Change of BORO yield in 2090's

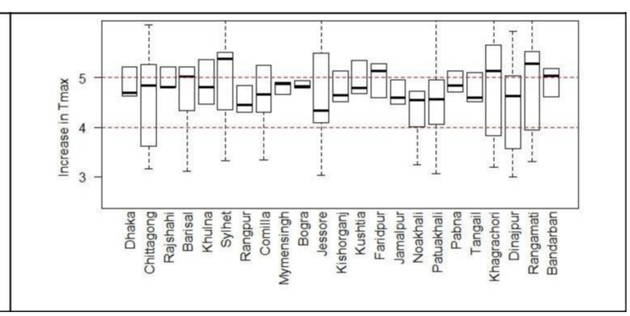

Fig.3: Increase of maximum temperature in 2090's

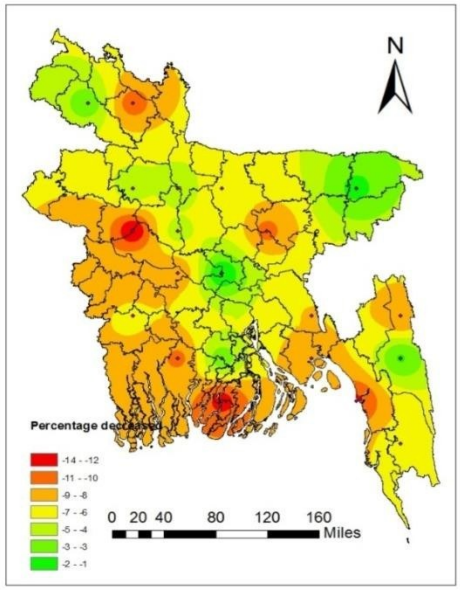

Fig. 4: Change of the yield of Boro rice in mid future (2050's)

CONCLUSION

Most of the regions encountered extreme change in maximum and minimum temperature over the emergence to end period of BORO crop. The yield trend is gradually decreasing at an alarming rate; crossing 10% decrease in 2020's to 20% decrease in 2090's. The growth and yield of crops are directly related to the rate of photosynthesis and their response to temperature, solar radiation and rainfall. Optimum temperatures for maximum photosynthesis range from 25ºC to 30ºC for rice under the climatic conditions of Bangladesh. Increased temperatures during the growing season cause grain sterility. (Basak et al., 2010). Maximum temperatures cause the reduction in rice yield mainly. However CO_2 is also increasing which pose a positive impact on crop production. But, it is not dominant over the impact of temperature. The core finding in our predicted results suggest that, keeping the harvesting date same or shortening the emergence to harvest duration, we can actually get an increased yield in most of the regions. However, due to shortening the growth period, we are also shortening the irrigation water to a significant amount. This amount might be sufficient for many regions, but possibly not for the drought prone regions. Moreover, the growing period of BORO rice experiences no Monsoon at all. For this reason, the probable cause behind the reduction in yield of any zone is supposed to be drought. This finding calls for a more detailed works on SPI (standardized precipitation index) in future. DSSAT crop modeling could prove very effective for this potential study. Moreover, the high end emission as the IPCC could be simulated to assess how intense is the impact of increased emission on Boro rice.

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