International conference on Climate Change in relation to Water and Environment (I3CWE-2015)
Department of Civil Engineering
DUET - Gazipur, Bangladesh

IMPACT OF HIGH END CLIMATE CHANGE ON BORO PRODUCTION OF BANGLADESH

M. G. R. Fahad[1], M. A. Hasan[2], A.K.M.S. Islam[3], S. K. Bala[4] and G.M. T. Islam[5]

ABSTRACT: The article provides an assessment of Boro rice production using DSSAT 4.5 model under various aspects of future climate change, as projected by IPCC. The predicted 2°C to 4 °C rise of temperature by the end of the 21st century poses a threat to rice production throughout the world where temperatures are above the optimal range (22°C -28°C) for growth. Any further increase in mean temperature or episodes of high temperatures during sensitive stages will reduce rice yields drastically. Trend analysis of necessary climatic parameters like Tmax, Tmin and solar radiation manifests an average of 0.02°C per year increment of daytime and nighttime temperature with a decreasing solar radiation of 0.02MJ/m^2/year. Also, the outcomes of simulation substantiate an average of 11.0% and 4.3% reduction of yield (kg/ha) due to the warming and deficient solar radiation, respectively. Comparing reduction of yields signify that Chittagong, Rajshahi and Barisal as most vulnerable to climate change. Thus, it is high time to understand potential impact of climate change on Boro rice is important for the development of appropriate strategies to adapt and to mitigate the likely outcomes on long-term food security of Bangladesh.

Keywords*: Bangladesh, Boro, climate change, DSSAT, rice, temperature*

1. Introduction

Impact of climatic changes and unfavorable weather events on the rice production is inevitable(Peng et al. 2004) Changes in air temperature, rainfall pattern, solar radiation, carbon dioxide etc. brought about by climate change are likely to affect rice production system directly and indirectly(Ali 1999). Changes on natural state and pattern of weather will also translate to the changes on different farm practices involved in the agricultural production system. According to the IPCC 4th assessment (AR4), agricultural production in South Asia could fall by 30% by 2050 if no action is taken to combat the effects of increasing temperatures and hydrologic disruption(Pachauri and REisinger 2007).Being an agricultural country of south Asia, Bangladesh will also face challenges in food security due to the impact of climate change on the rice production. Boro rice is currently accounts for about 50% of the total rice production of the country. Thus it is imperative to assess the impact of the future climate change on Boro rice production to develop different adaptation measures. Any deterioration of rice yield through climate change would seriously impair food security of this country.

[1] Md. Golam Rabbani Fahad, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology (BUET), fahad.ce08@gmail.com
[2]Mohammad AlfiHasan[1]Institute of Water and Flood Management, Bangladesh University of Engineering and Technology (BUET), Bangladesh, mdalfihasan19@gmail.com
[3] A.K.M Saiful Islam, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology (BUET), Bangladesh, akmsaifulislam@iwfm.buet.ac.bd
[4]Sujit Kumar Bala, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology (BUET), Bangladesh, bala@iwfm.buet.ac.bd
[5] G.M Tarekul Islam, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology (BUET), Bangladesh, tarek@iwfm.buet.ac.bd

Rice plant is sensitive to weather. The predicted 2–4 °C increment in temperature by the end of the 21st Century poses a threat to rice production(Shah *et al.* 2011). Study reveals that exposure to high temperature for a few hours can greatly reduce pollen viability, spikelet sterility in rice and, therefore, reduce grain yield (Wassmann et al. 2009). In a separate study, the simulated yield reduction from a 1ºC rise in mean daily temperature varied from 5-7% for major crops, including rice(Matthews et al. 1997).Experimental studies indicate that increased temperature(Basak *et al*. 2010) and decreased radiation (Evans and De Datta 1979)can reduce yield. Therefore, the challenges are faced by the agricultural sectors from the climatic conditions require systematic integration of environmental and economic development measures for a sustainable agriculture growth. In this context, a crop growth model known as Decision Support System for Agrotechnology Transfer (DSSAT 4.5) can be a viable tool to understand the climate impact on agriculture. Therefore, this tool is used in this study to assess the potential climate change impact on Boro rice production of Bangladesh. The analysis has been done to identify the most vulnerable rice growing location in Bangladesh for changing climatic conditions and hydrological properties of soil and to assess the possible change in Boro rice yield under the historical period and future period as per IPCC's assumptions.

2. Materials and Methodology

2.1. Simulation location and rice variety selection

Seven major Boro rice growing regions (20%-60%) i.e. Rangpur, Rajshahi, Shylet, Dhaka, Comilla, and one coastal region i.e. Khulna is selected as the study area. Model response to diverse weather and management conditions substantially subjected to different genetic coefficients. The Boro rice variety BR14 has been selected because genetic coefficients for this variety are available in the DSSAT modeling system which is given in Table 1 and also the effects of climate change and variability on this variety provides insights into the possible impact of climate change on Boro rice yield in the future.

Table 1: Genetic coefficients for rice cultivar, grown in Bangladesh

Rice	Cultivar	Coefficients								Source
Boro	BR14	P1	P2R	P5	P2O	G1	G2	G3	G4	DSSAT 4.5
		560	200	500	11.5	45	0.026	1	1	

Definition of each coefficient is given below:

- P1: Time period from seedling emergence during which the rice plant is not responsive to changes in photoperiod.
- P2O: Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate.
- P2R: Extent to which phasic development leading to panicle initiation is delayed for each hour increase in Photoperiod above P2O.
- P5: Time period from beginning of grain filling to physiological maturity with a base temperature of 9°C.
- G1: Potential spikelet number coefficient as estimated from the number of spikeletes per g of main culm dry weight at anthesis.
- G2: Single grain weight (g) under ideal growing conditions.
- G3: Tillering coefficient relative to IR64 cultivar under ideal conditions.

- G4: Temperature tolerance coefficient.

2.2. Assemblage of crop management, soil and weather Data

Crop management data requirement for BR14 variety includes: planting method, transplanting date, planting distribution, plant population at seedling, plant population at emergence, row spacing, plant per hill, fertilizer application dose, and irrigation application and frequency are collected from Bangladesh Rice Knowledge Bank (BRKB, 2014). The soil profile of selected simulation locations are assembled from DSSAT WISE 1.1 Soil Profile Database for Crop Models. Weather data includes the daily average maximum and minimum temperature, precipitation, solar radiation, humidity and wind speed from 1975 to 2010 were collected from Bangladesh Meteorological Department. First, the simulation is conducted for 2008 to predict Boro rice yield for the major eight rice-growing locations. One of the major goals of this research work is to see the effect of climatic parameters on Boro rice production under various climatic scenarios. The monthly average maximum and minimum temperature, sunshine hour and rainfall from 1975 to 2013 are collected from the Climate and Land Resource Information Database of Bangladesh Agricultural Research Council. These data are used to assess the trends of yearly average variation during crop growing months (January to May). In each case, only linear trend is assessed for 35 years (1975-2010) and the nature of increasing or decreasing is distinguished.

2.3. Simulation with DSSAT 4.5

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 (Jones, Hoogenboom et al. 2003)have provided a detailed description of the model. Using weather parameters, soil and crop management inputs, the yields of BR14 for the year 2008 for eight stations i.e. Rangpur, Rajshahi, Shylet, Dhaka, Comilla, Khulna, Chittagong and Barisal are 6571, 7330, 7099, 6524, 7645, 4007, 7189 and 6913 Kg/Ha respectively. Sensitivity of rice yield under varying temperature and solar radiation conditions are also simulated to analyze future change of yield due to climate change.

3. Results and Discussion

Levels of rice yields depended not only on the climatic conditions, but also on field soils and capability of management (crop, irrigation, fertilizer, tillage and harvest). Simulation with DSSAT 4.5 model exhibits yield varies substantially across the selected seven stations with mean yield of 7,031 ± 3,000 kg/ha and range of 4,007–7,645kg/ha. Rajshahi and Comilla exhibits highest yield compared to other station where as yield of Khulna region is the lowest. According to figure 1 Trend analysis of the average monthly maximum temperature during crop growing months reveals increasing trend for February, March, April and May with a rate of 0.04°C, 0.02°C, 0.04°C, 0.01°C per year respectively.

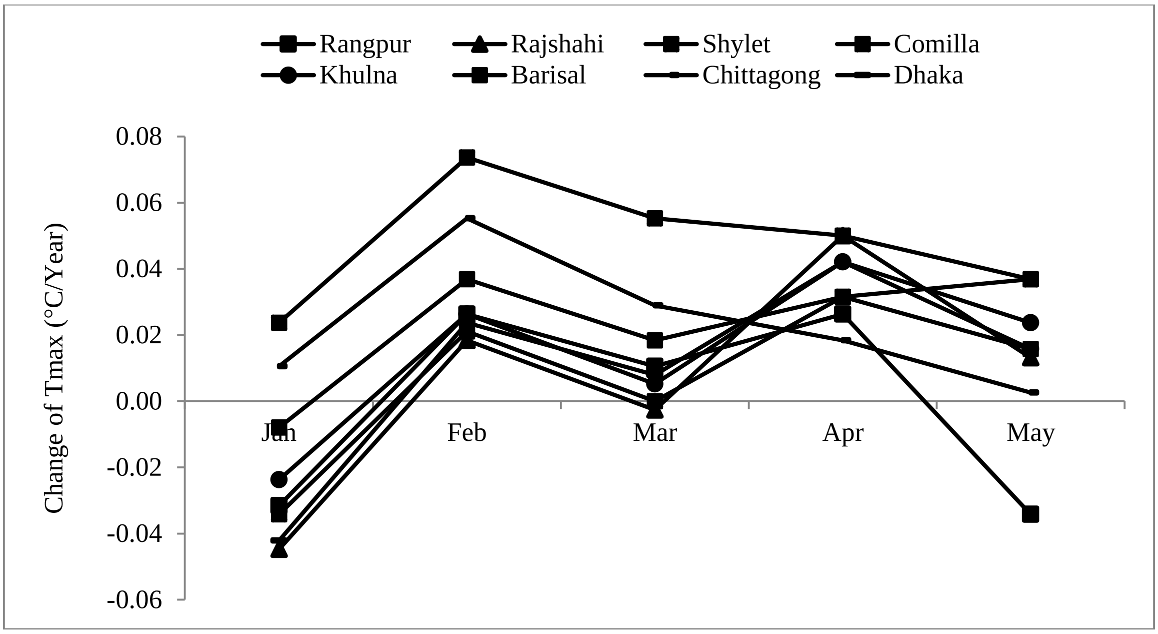

Figure 1: Changes in monthly average maximum temperature per year during 1975-2010

Similar increasing trend for the average monthly minimum temperature has also observed with a rate of 0.03°C, 0.03°C, 0.02°C, and 0.02°C per year as shown in figure 2. Although increment of temperature during vegetative phase is less, increase of hotter day and night will cause subsequent decrease in Boro yield. Gradual increases in temperature, as reflected in trend analysis have serious implications for agricultural production.

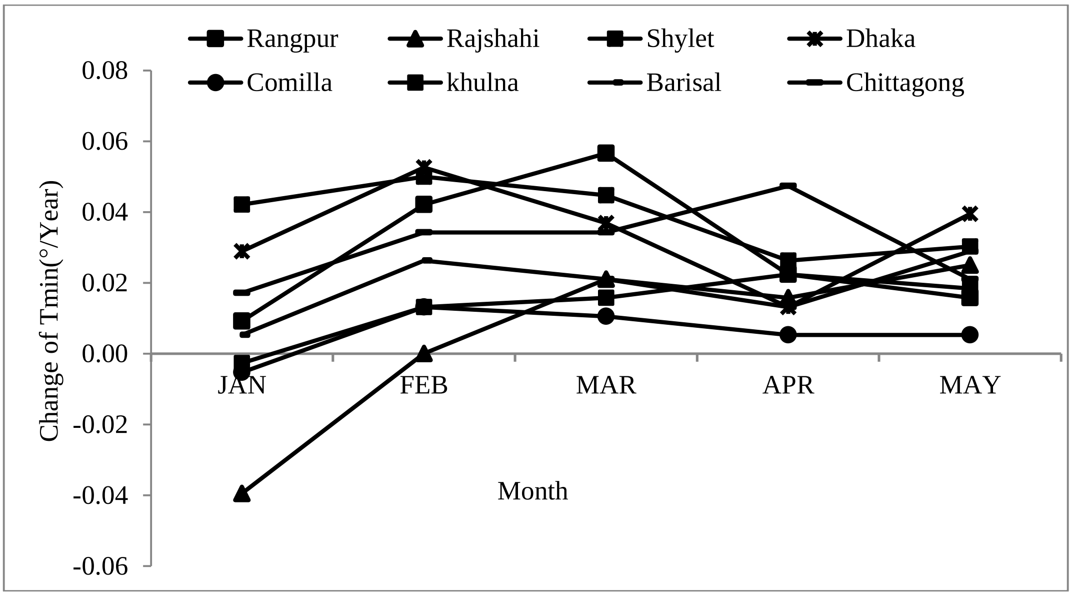

Figure 2: Changes in the monthly average minimum temperature per year during 1975-2010

For rice growth, the extreme maximum temperature is of particular importance during the maturing and flowering stages. Exposure to the high temperature for a few hours can greatly reduce pollen viability and, therefore, cause yield loss. Spikelet sterility is greatly increased at temperatures higher than 35 °C. Outcomes of trend analysis signify an inimical threat to Boro production in the future. Sensitivity of yield to increased daytime temperature (T_{min}) and nighttime temperature (T_{min}) shows confound negative impact on Boro production.

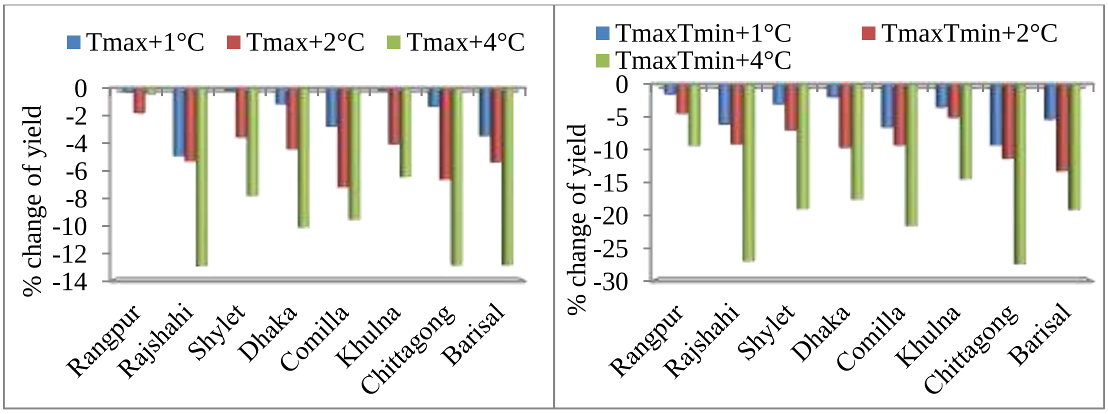

Figure 3: Changes in of yield with increase temperature

According to Figure 3 by Increasing T_{max} to 1°C, 2°C and 4°C exhibits drastic reduction of yield ranging from 0.2% to 13%. From Figure 3 the combined effects of Tmin and Tmax indicate that warming has an indisputable negative impact on rice yield resulting from 1.25% up to 27% reduction of yield. Majority of rice is currently grown in study regions where current temperatures are already close to optimum for rice production. Therefore, any further increases in mean temperatures or of short episodes of high temperatures during sensitive stages may be supraoptimal and reduce grain yield. According to Figure 3 27.13% and 27.58% reduction of yield manifest Rajshahi and Chittagong as most vulnerable to temperature escalation, respectively. Rangpur and Khulna region are less susceptible to warmer climatic condition.

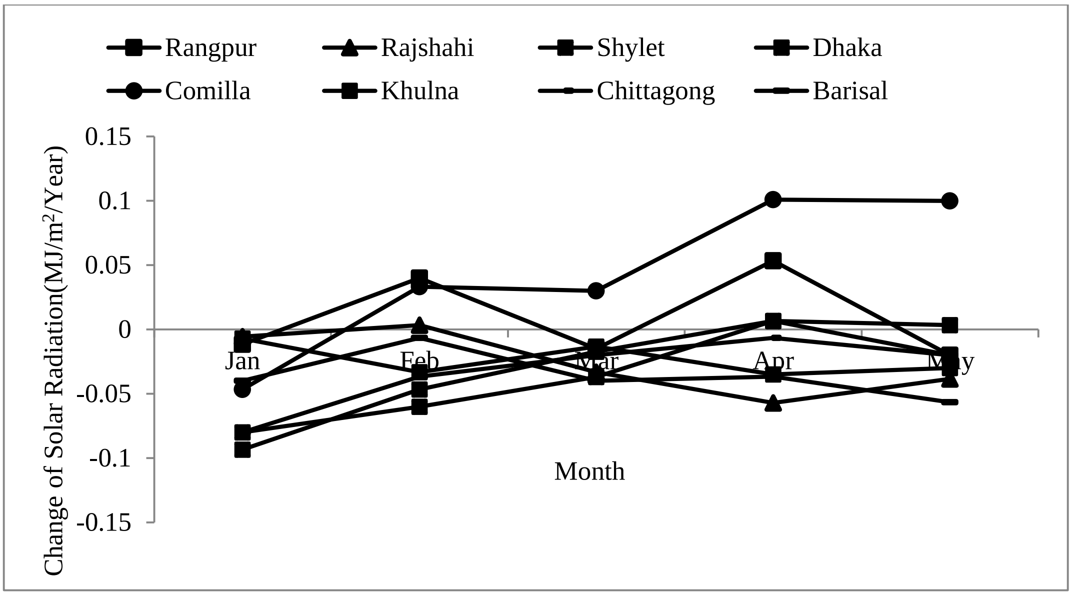

Figure 4: Changes in the monthly average solar radiation per year during 1975-2010.

Trend analysis of monthly average solar radiation demonstrates variegated outcome. From figure 4, it shows that all simulation stations show an average of 0.05 MJ/m^2/year decrease in January. Except Comilla and Rangpur, other stations exhibits monthly solar radiation decreases in March, April and May with an average rate of 0.02, 0.01, 0.02 MJ/m^2/year respectively. Sensitivity analysis demonstrates yield increases upto 6.3% with increased solar radiation. Deficiency of solar radiation results in less yield. According to figure 5, negative trends during January month with an average of -0.05MJ/m^2 implies lesser solar radiation. Noticeable declining solar radiation trend has also observed in crop ripening period (May). Shading during the vegetative and reproductive stage has a profound effect on the spikelet number. During ripening it reduces grain yield considerably because of a decrease in the percentage of filled spikeletes.

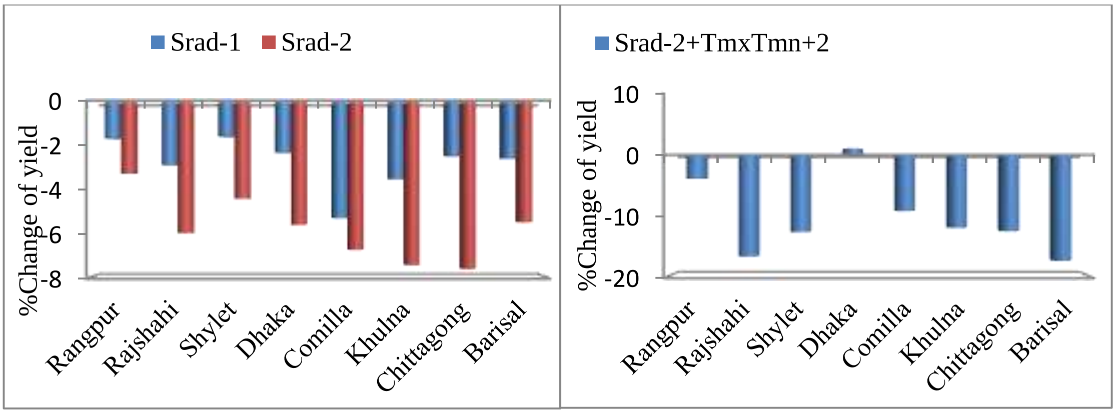

Figure 5: Changes in of yield with solar radiation

Sensitivity analysis demonstrates that yield increases with solar radiation ranging from 1.39% to 6.29%. But trend analysis from figure 4, validates decrease in solar radiation. By decreasing solar radiation to 1 MJ/m^2 and 2 MJ/m^2 results in a reduced yield. As shown in figure 5 Khulna and Chittagong is the most vulnerable region with an average of 6.75% reduction of yield. It is also noticed that Boro yield is more susceptible to temperature increase rather than reduced solar radiation. From the trend analysis of temperature and solar radiation it is evident that future climate will be warmer with a reduced solar radiation for the simulation stations. According to figure 5 the combined effect of temperature and solar radiation manifests, except Dhaka, all seven stations gives reduced yield. According to figure 5 reduction of yield in Rajshahi and Barisal is 16.78% and 17.69%, respectively. Also average reduction of yield for Rangpur, Shylet, Khulna and Chittagong is 10.01%. Also Northern and South-east region part of Bangladesh shows 5.97% more reduction than other regions concluding they are more vulnerable to future climate change.

4. Conclusion

The estimated impacts of weather variables on Boro production on different location of Bangladesh enable us to predict the future scenarios of food production. Trend analysis of the weather variables from 1975 to 2010 provides a guidance to predict the future weather condition. Our finding of a negative impact of higher maximum and minimum temperature and reduced solar radiation during the vegetative and ripening phases which is the most crucial. Identifying most vulnerable regions to future adverse climate condition is a noteworthy task. Farmers can adapt to climate change to some degree by shifting planting dates, choosing varieties with different growth duration, or changing crop rotations. It is important that proper genetic coefficients of rice variety should be determined in a sophisticated and controlled way. It is also imperative to develop high temperature-resistant rice varieties and modify 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.

5. Acknowledgement

The research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under grant agreement no 603864.

6. References

Ali, A.. "*Climate change impacts and adaptation assessment in Bangladesh.*" Climate Research 12(2-3): 109-116, 1999.

Basak, J. K., et al. (2010). "*Assessment of the effect of climate change on boro rice production in Bangladesh using DSSAT model.*" Journal of Civil Engineering (IEB) 38(2): 95-108.

Evans, L. and S. De Datta (1979). "*The relation between irradiance and grain yield of irrigated rice in the tropics, as influenced by cultivar, nitrogen fertilizer application and month of planting.*" Field Crops Research 2: 1-17.

Jones, J. W., et al. (2003). "*The DSSAT cropping system model.*" European journal of agronomy 18(3): 235-265.

Matthews, R., et al. (1997). "*Simulating the impact of climate change on rice production in Asia and evaluating options for adaptation*." Agricultural Systems 54(3): 399-425.

Pachauri, R. and A. Reisinger, "*IPCC fourth assessment report.*" IPCC, Geneva, 2007.

Peng, S., et al. "*Rice yields decline with higher night temperature from global warming*." Proceedings of the National Academy of Sciences of the United States of America 101(27): 9971-9975, 2004.

Shah, F., et al. (2011). "*Impact of high-temperature stress on rice plant and its traits related to tolerance*." The Journal of Agricultural Science 149(05): 545-556.

Wassmann, R., et al. (2009). "*Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation*." Advances in Agronomy 102: 91-133.