Climate Change Impacts on Rice Production in Bangladesh: Results from a Model

উন্নয়ন অন্বেষণ
Unnayan Onneshan
The Innovators
centre for research and action on development

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Executive Summary

Climate is one of the major controlling factors for the well-being of the residents of the world. Global climate has been changing due to natural forcing as well as anthropogenic activities, especially emissions of greenhouse gases and aerosols, and land use changes in recent decades. Climatic factors such as temperature, rainfall, atmospheric carbon dioxide, solar radiation etc are closely link with agriculture production. Therefore, rice production would be major concern in recent years due to changing climatic conditions, because there is a significant amount of rice yield may hamper for only fluctuations of those climatic parameters.

A simulation study has been conducted to assess the vulnerability of Boro rice production (58% of the total rice production during 2008) in Bangladesh to see the effects of potential climate change. Effects of climate change on yield of Boro rice have been assessed using DSSAT (Decision Support System for Agrotechnology Transfer, version 4) for six major rice-growing regions. Soil and hydrologic characteristics of these locations, and typical crop management practices, traditional growing period and weather data in 2008 were used in the simulations. Sensitivity analysis was carried out for increasing maximum and minimum temperature for 2^0C and 4^0C and different level CO_2 concentrations (50 ppm, 100 ppm and 200 ppm) above the value reported in 2005 of IPCC Fourth Assessment Report (379 ppm).

The maximum Boro rice production has been predicted in Comilla (5427 kg/ha) and minimum in Rajshahi (3102 kg/ha) in 2008. It was also found that the average production at Barisal, Comilla and Sylhet district was above 5000 kg/ha, whereas in Rajshahi and Satkhira it was below 4000 kg/ha. Therefore a certain amount of Boro rice production varied at different locations in Bangladesh for different climatic conditions and hydrological properties of soil (variety and management practices of Boro rice were same for all simulations). Comparing to the simulation results of rice production on location-wise, it is clear that Rajshahi is the most vulnerable rice-growing region where climatic parameters play the dominant factors and significant fluctuation of day and night temperature in winter season in Bangladesh.

The model results show that the effects of maximum temperature would drastically reduce rice yield at all selected locations. Boro rice yields reduce at range of 2.6 to 13.5% due to increase 2^0C maximum temperature and 0.11 to 28.7% for 4^0C maximum temperature (base year 2008). The average value (average percentage change of rice yield for 6 locations) of Boro rice yield reduction is 6.10% and 16.0% in case of 2^0C and 4^0C for increasing maximum temperature, respectively. As like as maximum temperature, minimum temperature have also negative impacts on Boro rice yields that reduce 0.40 to 13.1% due to increase 2^0C and 0.11 to 15.5% for 4^0C minimum temperature. The average figure of yield reduction for minimum temperature is 4.2% for 2^0C and 8.5% for 4^0C. Therefore, maximum temperature is more vulnerable and negative impact on rice yield compared to the minimum temperature. Combined effects of maximum and minimum

temperatures are more significant compared to their individual effect on rice production in Bangladesh. Boro production drastically reduces for increasing maximum and minimum temperature 2^0C and 4^0C and it may be 3.2 to 18.7% and 5.3 to 36.0% for rising temperature both 2^0C and 4^0C, respectively. The average figure of yield reductions of the two temperature parameters is 10.4% for 2^0C and above 22.9% for 4^0C.

Increasing atmospheric CO_2 concentration is likely to have some positive effect on rice yield, but the effect is not so significant compared to the negative effect of temperature. If the level of atmospheric CO_2 concentrations have been increased 50 ppm from the year of 2005 (IPCC reported value 379 ppm), Boro rice yield increased 2.1 to 4.4% and it was 4.0 to 9.6% for 100 ppm and 5.2 to 18.2% for 200 ppm. The average value is 3.5%, 6.5% and 12% for 50 ppm, 100 ppm and 200 ppm CO_2 concentrations, respectively. The simulation study has been also conducted under different climatic scenarios of temperature and carbon dioxide concentration. Maximum scenarios show the negative effect on rice production in Bangladesh. Scenario likes, Tmax 2^0C+ Tmin 2^0C+200 ppm CO_2 has some positive effect on rice production (1.37% yield increased) but those positive effects are not considerable amount compared to the negative effect of other scenarios. The most significant negative scenario is Tmax 4^0C+ Tmin 4^0C+50 ppm CO_2 (24.7% yield reduced). Variations of rainfall pattern over the growing period have also been found to affect rice yield. Year-wise rice yield was also predicted on the basis of historical and IPCC assumptions and the greatest yield reduction was observed with considering IPCC assumptions in the years 2020, 2030, 2040 and 2050.

Section 01

1.1 Introduction

Agriculture is always vulnerable to unfavorable weather events and climate conditions. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are important factors, which play a significant role to agricultural productivity. The impacts of climate change on agriculture food production are global concerns and for that matter Bangladesh, where lives and livelihoods depend mainly on agriculture, is exposed to a great danger, as the country is one of the most vulnerable countries due to climate change.

Bangladesh has a large agrarian base with 76 percent of total population is living in the rural areas and 90 percent of the rural population directly related with agriculture. Increasing food production and attaining food security in Bangladesh require sustainable growth of agricultural sector. The Agro-Economic contribution is 20.83 percent of the Gross Domestic Product (Bangladesh Economics Review, 2009). In agricultural sector 48.1 percent of the country's labor force is always vulnerable to changing climate conditions and unfavorable weather events. The sector is already under pressure for increasing food demand, problems associated with agricultural land and water resource depletion. The issues of climate change make the pressure more acute for the sector.

Rice is the staple food for above 150 million populations. The population growth rate is 2 million per year. According to this rate, the total population will become 233.2 million within 2050. However, she faces a tremendous challenge for providing food security to the increasing population. Therefore, it is imperative to increase rice production in order to meet the growing demand for food emanating from population growth. Although, there have been ups and downs in the domestic production of food grain. The diverse climatic phenomena like cyclone, drought, changing rainfall patterns and temperature; there has been a significant lost in food grain production in every year. For example, two rounds of floods and devastating cyclone Sidr in 2007 and cyclone Aila in 2009 caused severe damages in agriculture production, especially the rice production. 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.

1.2 Objectives of the Study

- Assessment of possible change in yield of selected Boro rice variety due to climate change using DSSAT crop model
- To identify the most vulnerable rice growing location in Bangladesh for changing climatic conditions and hydrological properties of soil
- Assessment of possible change in Boro rice yield under Historical and IPCC assumptions
- The study proposes policy recommendations to improve Boro rice production from upcoming diverse climatic situations

Section 02

2.1 Selection of Simulation Locations

The simulation study was conducted for six major rice growing locations in Bangladesh. Among them, Rajshahi was selected from Rajshahi division; Mymensingh was selected from Dhaka division; Satkhira from Khulna division; Barisal from Barisal division; Comilla from Chittagong division; and Sylhet district from Sylhet division. It has been also mentioned that the weather and soil data were also collected for those selected locations.

2.2 Selection of rice variety

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 cultivar. The Boro rice variety BR3 has been selected in the present study because genetic coefficients for this variety are available in the DSSAT modeling system. Although this variety is not widely used at present time, the effects of climate change and variability on this variety provides insights into possible impact of climate change on Boro rice yield in the future. 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 field and laboratory experiments for 1 to 2 years field experiment. The genetic coefficients of BR3 Boro rice variety are given in Table 1.

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

Rice	Cultivar	Coefficients								Source
		P1	P2R	P5	P2O	G1	G2	G3	G4	
Boro	BR3	650.0	90.0	400.0	13.0	65.0	0.025	1.0	1.0	DSSAT v4

2.3 Crop Management Data

Crop management data required by the model include 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 were collected from Bangladesh Rice Research Institute (BRRI, 2009). The major crop management input data used in the model for all simulations in the present study are shown in Table 2.

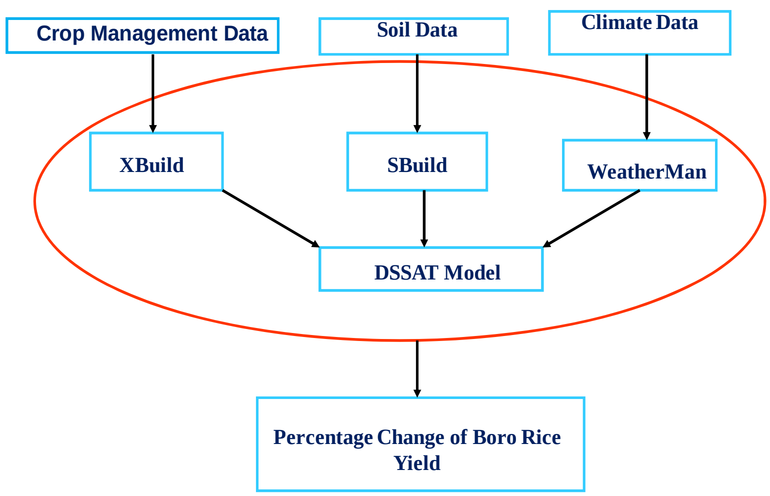
Table 2: Crop management data used in the model

Parameter	Input data
Planting method	Transplant
Transplanting date	15 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
Transplant age	35 days
Plant per Hill	2
Fertilizer (N) application	
• 18 days after transplanting	30 kg ha^{-1}
• 38 days after transplanting	70 kg ha^{-1}
• 56 days after transplanting	25 kg ha^{-1}
Application of irrigation	860 mm in 14 applications

2.4 Crop Model (DSSAT)

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, non-irrigated rice and other crops like wheat, potato etc, 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.

DSSAT Model Flow Diagram



2.5 Soil Data

Soil data (percentage of clay, silt and stones, organic carbon, cation exchange capacity, pH in water, etc) were collected from Soil Resources Development Institute (SRDI), Dhaka and Bangladesh Rice Research Institute (BRRI), Gazipur. As an example, the soil profile data used in the model (i.e., Agro-Ecological Zone, AEZ-19) covering Kishoregani, Habigang, Bramanbaria, Comilla, Chandpur, Feni, Noakhali, Laksmipur, Narsingdi, Narayanganj, Dhaka, Shariatpur, Modaripur, Gopalganj and Barisal districts is presented in Table 3.

Table3: 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/100gm**	**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

2.6 Weather Data

Weather data included daily average maximum and minimum temperature, daily precipitation, carbon dioxide, etc in 2008 were collected from BMD. First, the simulation study is conducted for 2008 to predict Boro rice yield for the major six rice-growing locations under 2008 climatic parameters. 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 Intergovernmental Panel on Climate Change (IPCC) considers four families of socio-economic development and associated emission scenarios, known as Special Report on Emissions Scenarios (SRES) A2, B2, A1, and B1. Depending on the SRES emission scenario and climate models considered, global mean surface temperature is projected to rise in a range from 1.8°C (with a range from 1.1°C to 2.9°C for SRES B1) to 4.0°C (with a range from 2.4°C to 6.4°C for A1) by 2100. On the basis of the Fourth Assessment report of IPCC (2005), the assumptions of maximum and minimum temperatures were considered 2^0C and 4^0C. Another important climate change is the increase in atmospheric carbon dioxide (CO_2) concentrations. Depending on the SRES emission scenario, the atmospheric CO_2 concentration is projected to increase from ≈379 ppm to >550 ppm by 2100 in SRES B1 to >800 ppm in SRES A1FI. Here we considered to increase carbon dioxide at a level of 50 ppm, 100 ppm and 200 ppm with 379 ppm to see their individual and combined effect on rice yield. From the analysis of historical data of rainfall over the last 30 years (1976-2005), shows decreasing trend of rainfall pattern in winter season among the most weather stations in Bangladesh. This trend is also consistent with the general climate change predictions (IPCC, Third assessment report).

On the basis of rainfall trend in winter season and various predictions results, this simulation study has been conducted to reduce rainfall amount 5 mm and 10 mm to see the effect on rice production in Bangladesh.

Section 3

3.1 Model Simulations

The predicted yields Boro rice variety, at six major rice growing locations of Bangladesh is shown in Fig. 1. These predictions have been made using a fixed concentration of atmospheric CO_2 of 379 ppm (the value reported for the year 2005 in the Fourth assessment report of IPCC), irrigation application (860 mm in 14 applications), fertilizer dose (125 kg/ha in 3 applications of nitrogen) and for planting date of 15 January. Soil data and climate data were varied on location basis. From the model simulation it is observed that maximum Boro rice production has been found for Comilla district (5427 kg/ha) and minimum was Ragshahi (3102 kg/ha) in 2008. It has been also found that the production at Barisal, Comilla and Sylhet district above 5000 kg/ha, whereas in Rajshahi and Satkhira it was below 4000 kg/ha. Therefore, a certain amount of Boro production varied at different locations in Bangladesh for different climatic and hydrological properties of soil (variety of Boro rice was same for all simulations). Comparing the simulation results of rice production on location-wise, it is clear that Rajshahi is the most vulnerable rice growing region where climatic parameters play the dominant factors and significant fluctuation of day and night temperature in winter season. The average Boro production in this six locations in Bangladesh was 4564 kg/ha in 2008.

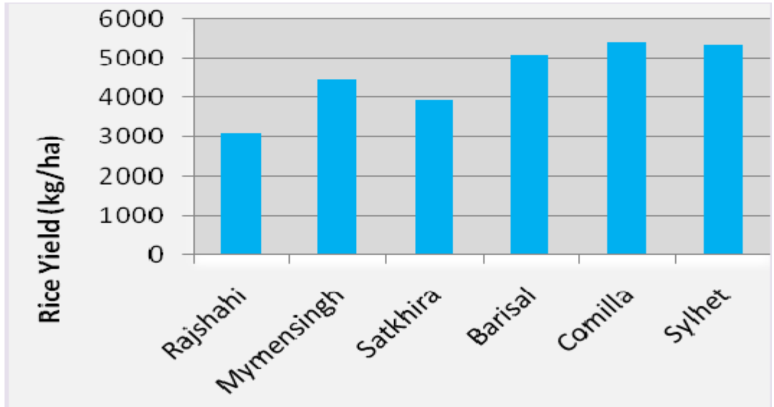


Fig. 1: Location-wise prediction of rice yield in 2008

3.2 Effects of Maximum temperature (Tmax) on Boro rice production

The growth and yield of crops are directly related to the rate photosynthesis and phenology, and their response to temperature. Optimum temperatures for maximum photosynthesis range from 25 to 30^{0}C for rice under climatic conditions of Bangladesh. The model results show that the effect of maximum temperature would drastically reduce rice yield at all selected locations except Sylhet (increased 2^{0}C temperature).

Maximum Temperature has significant negative impacts on Boro rice yield that reduce about 2.6 to 13.5% due to increase 2^{0}C maximum temperature and 0.11 to 28.7% for 4^{0}C maximum temperature**.** Figure 2 shows that the maximum temperature has the most significant negative impact on Satkhira district for both 2^{0}C and 4^{0}C temperature increased and minimum impact on Sylhet district. From the analysis of daily average maximum temperature, it has been found that the monthly average maximum temperature at Satkhira in January, February, March, April and May (growing season of Boro rice) were 25.3^{0}C, 26.7^{0}C, 32.5^{0}C, 34.9^{0}C and 36.1^{0}C, respectively in 2008. Analyzing of monthly average maximum temperature over the last 30 years (1976-2005), it has been also found that temperature increases 1.18^{0}C, 0.064^{0}C, 0.975^{0}C and 0.852^{0}C in February, March, April and May month, respectively which represent the most critical period for Boro production in Bangladesh. These increasing trends are significantly higher compared to the IPCC assessment. Increased maximum temperature 2^{0}C above, the average value, yield reduction was above 13% and for 4^{0}C, it was above 28% at Satkhira. Similarly, the monthly average maximum temperature at Rajshahi in January, February, March, April and May were 23.7, 25.7, 33.0, 36.3 and 35.6, respectively. Increasing maximum temperature 2^0C and 4^0C above, the average value, yield reduction was 2.6 % and 12.7%, respectively. Similar results are also found for other locations in Bangladesh but the percentage changes of rice yields are different. Maximum temperature effect on rice production at Sylhet location is not so significant compared to the other locations in Bangladesh under those scenarios (Fig. 2). The average value (average percentage change of rice yield for 6 locations) of yield reduction for maximum temperature was above 6% for 2^0C and above 16% for 4^0C (Fig. 3).

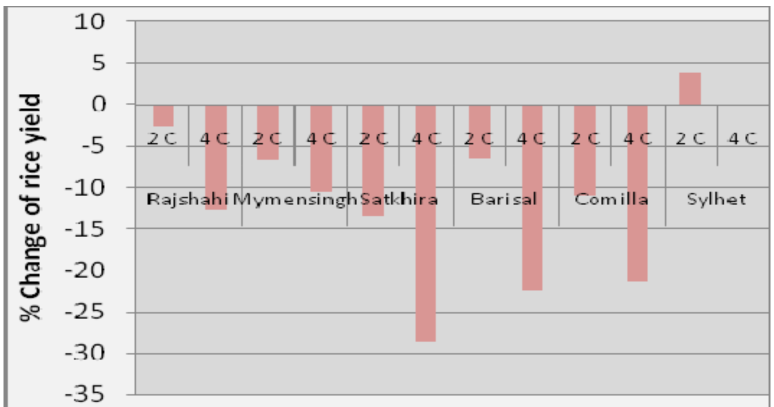


Fig. 2: Percentage Change of Boro rice yield under various scenarios of maximum temperature

(Source: Author's own calculation)

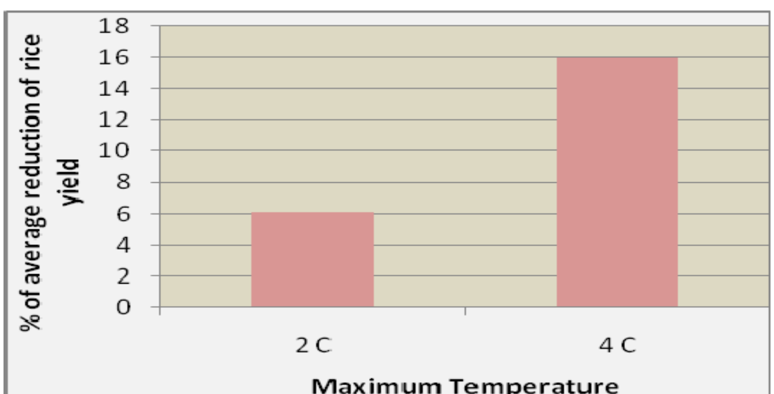


Fig. 3: Percentage of average reduction of rice yield for maximum temperature

(Source: Author's own calculation)

3.3 Effects of Minimum temperature (Tmin) on Boro rice production

In Bangladesh low temperature i.e. cold problem occurs in winter season usually during November to February when minimum temperature remains often below 20^0C. Sometimes minimum temperature occur bellow 20^0C in March and April in some parts of the country. A Boro crop encountering critical low temperature is appeared to suffer from cool injury. The extent of cool injury depends on the nature and duration of low temperature and diurnal change of low temperature and diurnal change of low (night) and high (day) temperature. The critical low temperature for a rice crop at agronomic panicle initiation (API), reduction division (RD) and anthesis are 18^0C, 19^0C and 22^0C, respectively.

As like as maximum temperature, minimum temperature have also negative impact on Boro rice yield that reduce about 0.40 to 13.1% due to increase 2^0C minimum temperature and 0.11 to 15.5% for 4^0C minimum temperature. Figure 4 shows that the negative impacts of minimum temperature at Satkhira district is more vulnerable compared to other five regions in Bangladesh. Calculated monthly average minimum temperature from daily average values were 12.5^0C, 14.5^0C, 22.0^0C, 24.1^0C and 24.9^0C in January, February, March, April and May, respectively in 2008 at Satkhira district. Analyzing of monthly average minimum temperature over the last 30 years (1976-2005), it has also found that temperature increased 1.21^0C, 0.50^0C, 0.695^0C and 0.831^0C in February, March, April and May month, respectively. Increased minimum temperature in 2^0C and 4^0C above those monthly average values, yield reductions were about 13% and 14%, respectively at Satkhira. Similarly, the monthly average maximum temperature at Comilla in January, February, March, April and May were 13.2^0C, 14.1^0C, 20.5^0C, 22.9^0C and 23.9^0C, respectively. Increasing maximum temperature 2^0C and 4^0C above those average values, yield reductions were 9.04 % and 15.5%, respectively. Similar results are also found for other locations in Bangladesh but the percentage changes of rice yields are different. Minimum temperature effect on rice production at Sylhet location is not so significant compare to the other locations in Bangladesh under those scenarios (Fig. 4). The average figure (average percentage change of rice yield for 6 locations) of yield reduction for minimum temperature was above 4% for 2^0C and above 8.5% for 4^0C

(Fig. 5). Therefore, maximum temperature is more vulnerable and negative impact on rice yield compared to the minimum temperature.

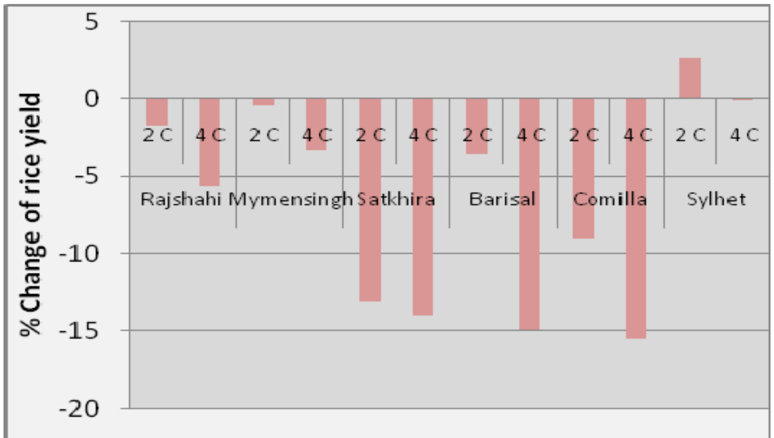


Fig. 4: Percentage Change of Boro rice yield under various scenarios of Minimum Temperature

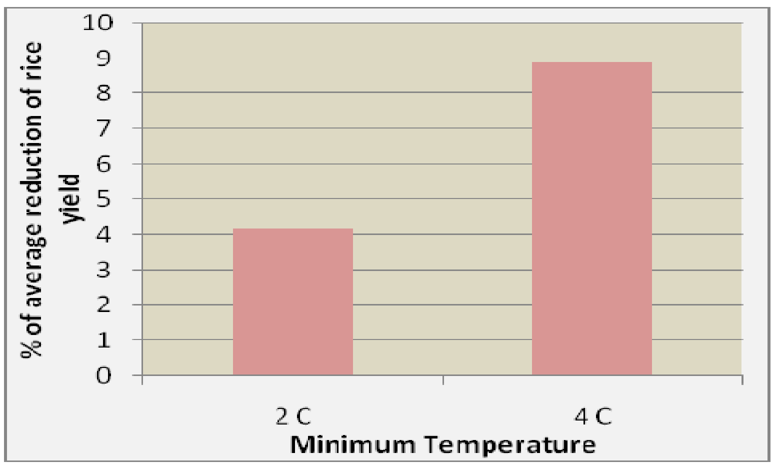


Fig. 5: Percentage of average reduction of rice yield for minimum temperature

(Source: Author's own calculation)

3.4 Combined Effects of Maximum and Minimum Temperature on Boro Rice production

Combined effects of maximum and minimum temperatures are more significant compared to their individual effect on rice production in Bangladesh except Sylhet (increased 2^0C temperature). Boro productions drastically reduce due to increase maximum and minimum temperature both 2^0C and 4^0C. For 2^0C, Boro rice yield reduction was 3.2 to 18.7% and for 4^0C, it was about 5.33 to 36.0%. The most effective area is Comilla district where yield reductions were 18.7% and 36.0% for their combination effect of 2^0C and 4^0C, respectively. The average figure (average percentage change of rice yield for 6 locations) of yield reduction of the two temperature parameters was above 10.4% for 2^0C and above 22.87% for 4^0C (Fig. 7).

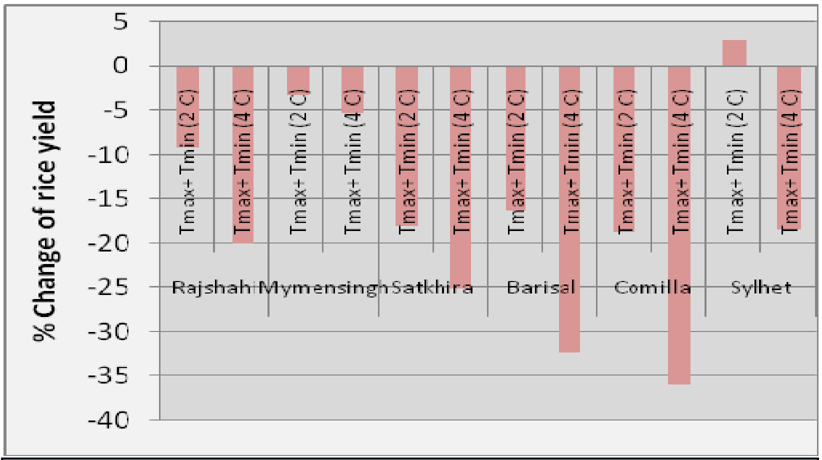


Fig. 6: Percentage Change of Boro rice yield under various scenarios of maximum and minimum temperature

(Source: Author's own calculation)

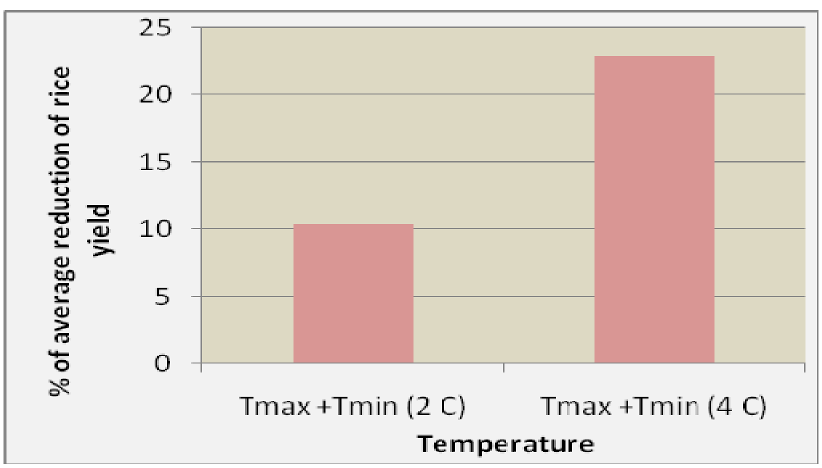


Fig. 7: Percentage of average reduction of rice yield for maximum and minimum temperature

(Source: Author's own calculation)

3.5 Effects of Carbon dioxide on Boro Rice production

CO_2 is vital for photosynthesis, and increases in CO_2 concentration would increase the rate of plant growth. Photosynthesis is the net accumulation of carbohydrates formed by the uptake of CO_2, so it increases with increasing CO_2. A doubling of CO_2 may increase the photosynthetic rate by 30 to 100%, depending on other environmental conditions such as temperature and available moisture (Parry, 1990).

Predicting rice yield under different concentrations CO_2 are shown in Figure 8. These predictions have been made using a fixed concentration of atmospheric CO_2 of 379 ppm (the value reported for the year 2005 in the fourth assessment report of IPCC) and then increased at a level of 50 ppm, 100 ppm and 200 ppm.

Increasing atmospheric CO2 concentration is likely to have some positive effect on rice yield. If the level of atmospheric CO_2 concentration increased 50 ppm from the year 2005 (IPCC reported value 379 ppm), Boro rice yields increase about 2.1 to 4.4% and it was 4.0 to 9.6% for 100 ppm and 5.2 to 18.2% for 200 ppm. The maximum positive effect of CO_2 has been found at Comilla district for 200 ppm concentration (yield increased above 18.0%) and minimum at Sylhet (only 5.2%).

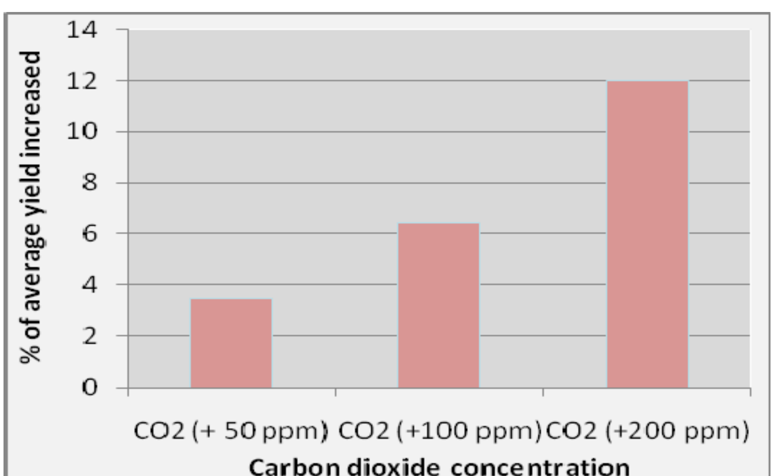


Fig. 8: Percentage of change of rice yield under various CO_2 concentrations

(Source: Author's own calculation)

3.6 Effects of Maximum Temperature (Tmax), Minimum Temperature (Tmin) and Carbon dioxide (CO_2) on Boro rice production

The simulation studies have conducted under different climatic scenarios of temperature and carbon dioxide concentration. Maximum scenarios show the negative effect on rice production in Bangladesh. Scenario likes, Tmax 2^0C+ Tmin 2^0C+200 ppm CO_2 has some positive effect on rice production but those positive effects are not so significant compared to negative effect of other scenarios. The most significant negative effect scenario is Tmax 4^0C+ Tmin 4^0C+50 ppm CO_2 (Comilla 33.1%). The various scenarios and their effects on rice production are shown in Figure 9.

From predicting rice yield under different scenarios, it is clear that temperature is one of the most dominant climatic factors, which affect rice production in Bangladesh significantly, and its effectiveness is very high, if it may raise 4^0C and CO_2 concentration 50 ppm.

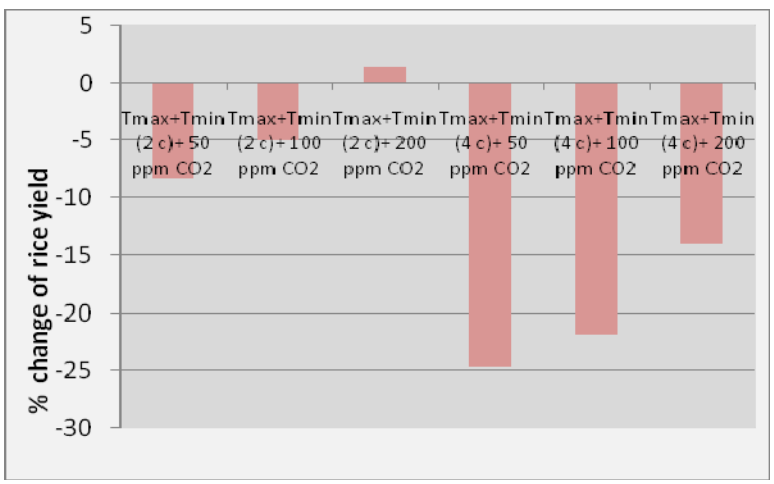


Fig. 9: Percentage of change of rice yield under various Climatic Scenarios

(Source: Author's own calculation)

3.7 Effects of Rainfall on Boro rice production:

Boro rice is an irrigated crop in Bangladesh, mainly depended on irrigation application water but the variability of rainfall in winter season is an important factor on Boro production in Bangladesh. Variability of rainfall affects the rice crop at different times. If the variability is associated with the onset of the rain, stand establishment and the growth duration of rice are affected. If variability is associated with an untimely cessation at the reproductive or ripening stage of the rice crop, yield reduction is severe.

From the analysis of historical data of rainfall over the last 30 years (1976-2005), shows decreasing trend of rainfall pattern in winter season among the most weather stations in Bangladesh. This trend is also consistent with the general climate change predictions (IPCC, Third assessment report). On the basis of rainfall trend in winter season and various predictions results, this simulation study has been conducted to reduce rainfall amount 5 mm and 10 mm to see the effect on rice production in Bangladesh.

Decreasing rainfall in winter season may have a significant negative impact on Boro rice production in future. Analysis of predicted rice yield shows that about 0.73 to 16.6% production may be reduced due to 5 mm rainfall and 3.33 to 24.2% for 10 mm rainfall reduction in winter season. A closer look shows that the maximum yield reduction (16.6% for 5 mm and 22.3% for 10 mm) is predicted in Rajshahi district, which represents drought prone region in Bangladesh (Table not shown). Depending on changes in rainfall patterns, the effects of rainfall on yield for other locations are different. The average figure (average percentage change of rice yield for 6 locations) of yield reduction was above 6% for 5 mm and above 14.3% for 10 mm (Fig. 10).

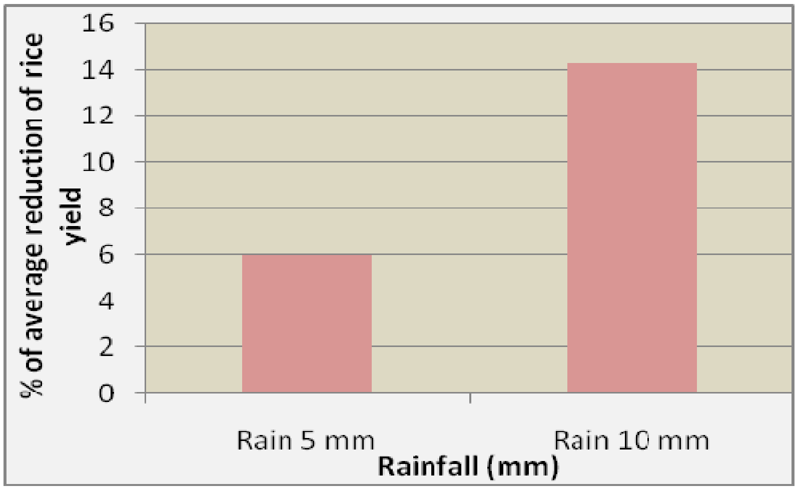


Fig. 10: Percentage of average reduction of rice yield for changing rainfall pattern

Table 4: Average percentage change of Boro rice yield under various scenarios	
Climate Change Phenomena	**% Change in Rice yield**
a) Temperature Effect	
Increased Maximum Temperature 2^0C	-6.09
Increased Maximum Temperature 4^0C	-16.0
Increased Minimum Temperature 2^0C	-4.17
Increased Minimum Temperature 4^0C	-8.9
Increased Tmax 2^0C+ Tmin 2^0C	-10.41
Increased Tmax 4^0C+ Tmin 4^0C	-22.87
b) Carbon dioxide Effect	
Increased 50 ppm CO_2	+3.47
Increased 100 ppm CO_2	+6.47
Increased 200 ppm CO_2	+11.97
c) Temperature and Carbon dioxide Effect	
Increased Tmax 2^0C+ Tmin 2^0C+50 ppm CO_2	-8.28
Increased Tmax 2^0C+ Tmin 2^0C+100 ppm CO_2	-4.95
Increased Tmax 2^0C+ Tmin 2^0C+200 ppm CO_2	+1.37
Increased Tmax 4^0C+ Tmin 4^0C+50 ppm CO_2	-24.66
Increased Tmax 4^0C+ Tmin 4^0C+100 ppm CO_2	-21.79
Increased Tmax 4^0C+ Tmin 4^0C+200 ppm CO_2	-14
d) Rainfall Effect	
Reduced 5 mm rainfall	-6.0
Reduced 10 mm rainfall	-14.3

3.8 Year Wise Prediction of Rice Yield

This simulation study has been also conducted for specific locations (Dinajpur, Mymensingh, Satkhira, Barisal, Comilla and Sylhet) and specific years (2020, 2030, 2040 and 2050) with considering the both historical data and IPCC assumptions. Those assumptions are assumed by simply trend line analysis. From the analysis of historical data over the last 30 years (1976-2005), it has found that the monthly average maximum and minimum temperatures increase about 0.02^{0}C per year and if this figure is extended up to the years 2020, 2030, 2040 and 2050, temperature may be increased 0.3^{0}C, 0.5^{0}C, 0.7^{0}C and 0.9^{0}C, respectively. The IPCC report says that temperature is projected to rise in a range from 1.8°C (with a range from 1.1°C to 2.9°C for SRES B1) to 4.0°C (with a range from 2.4°C to 6.4°C for A1) by 2100. On the basis of the IPCC repot temperature will increase at a rate of 0.042^{0}C per year and it may be 0.67^{0}C, 1.09^{0}C, 1.51^{0}C and 1.93^{0}C on the corresponding years. Similarly, carbon dioxide concentrations increased at a rate of 1.9 ppm per year and if it is increased for future predictions, those values are 409 ppm, 428 ppm, 447 ppm and 466 ppm for the years of 2020, 2030, 2040 and 2050, respectively (simply trend line analysis). Those assumptions are shown in Table 5.

Table 5: Year wise assumptions carbon dioxide concentrations and temperature data

Year	Historical Data Analysis		IPCC	CO_2
	Maximum Temperature	Minimum Temperature	Average Temperature	379 ppm in 2005
2008 (Base)	**0.02 ^{0}C/year**	**0.02 ^{0}C/year**	**0.042 ^{0}C/year**	**1.9 ppm/year**
2020	0.3	0.3	0.67	409
2030	0.5	0.5	1.09	428
2040	0.7	0.7	1.51	447
2050	0.9	0.9	1.93	466

3.9 Rice Yield under Historical and IPCC Assumptions

The historical assumptions is indicted a small amount of rice production may be changed on locations wise and it may be positive or negative trend. From the simulation studies, it is clear that except Satkhira and Barisal regions, rice production may be increased in future under those assumptions. Maximum positive effects of those assumptions are observed in Dinajpur and Sylhet. At the same time, rice yields are likely to fall sharply under IPCC assumptions. The most vulnerable regions are Satkhira, Barisal and Comilla where a significant risk of rice production is identified in 2050 and production may be lost above 9% (Table not Shown).

The results indicated that increased temperature results a small increase in rice yield which are compensated for increase in CO_2 for historical assumptions. The increasing rates of CO_2 are significantly higher compare to the temperature which is the main cause of yield increase of Boro rice. But the increasing trend of temperature 0.02^0C per year is not so consistent with present aspect and IPCC assumption because the emission rates of greenhouse gasses are comparatively higher than any previous situation. So, those historical assumptions are not reliable for future Boro rice production but it is important to find out the significance of those assumptions. On the other hand, rice yield drastically reduce in all scenarios for the IPCC assumptions. In IPCC assumptions, temperature increasing trend is two times greater than historical analysis but the CO_2 concentrations are same in year wise. As a result, significant yield reductions have occurred and the rates of reduction are significantly higher. The CO_2 fertilization effects are not able to offset the negative impacts of high temperature on rice yield which quite opposite to the historical assumptions. The average Boro rice production may be increased in 0.75%, 0.70%, 0.85% and 1.35% in 2020, 2030, 2040 and 2050, respectively for historical assumptions whereas, for IPCC assumptions, it may be declined at 1.3%, 2.5%, 4.40% and 5.40% in the corresponding years.

Section 4

4.1 Recommendations

Global and regional weather conditions are expected to become more vulnerable than the present time, considering increased in the frequency and severity of extreme events such as cyclones, floods, hailstorms, and droughts. By bringing greater fluctuations in crop yields and local food supplies and higher risks of landslides and erosion damage, they can adversely affect the stability of food supplies and thus food security. For example two round of floods and devastating cyclone Sidr in 2007 and cyclone Aila in 2009 caused severe damages in agriculture production, especially the rice production. There are some policy related guidelines which can help to take decision to improve rice production in future.

- Environmental conditions allover this country are not same. There are some heavy rainfall regions, some drought prone, some flooded and cyclone affected regions in Bangladesh. These natural phenomena are closely related with climatic conditions of these regions. So selection or develop temperature and drought tolerant rice varieties is one of the main criteria to increase rice production. Locations wise selection rice varieties depends on the environmental and hydrological criteria of those locations. It is also necessary to ensure sufficient fertilizer and irrigation application facilities on those locations during the rice growing period.
- Increasing productivity requires new knowledge-both to maintain yields and to improve the quality of production. The needed knowledge is primarily biological in nature, but also includes the social science and technical knowledge.
- Maximum agricultural researches in public sectors, very few number private organizations have directly relationship with agricultural research. But the private organizations may contribute a significant role to improve these sectors.
- In agricultural research, there is a small portion fund allocated over its entire funding and even smaller portion of research staff. There are not so available facilities to work more efficient and effective way of not only carrying out research, but also providing scientific leadership and encouragement to national programme.
- An important gap is the lack of weather stations in many districts, where climate change is expected to have important local impacts. These impacts can not be assessed perfectly without reliable weather data. Increased investment in regular and timely collection of weather data in local areas should therefore be accounted very high priority for protecting food security in the face of climate change in that region.

- There will need to be more reliance on scientific knowledge and assessment of viable options and bridging the gap among policy makers, research organizations, agricultural extension workers and farmers. Besides very few number of our farmers have knowledge about suitable growing period of crop, irrigation and fertilizer application schedule for adapting new climatic conditions.
- There should become a major priority area, if it is possible to integrate climate adaptation into national policies, strategies, programmes and budget related agricultural, forestry and fisheries. At last, Government of Bangladesh can take a proper policy to reduce negative impact in this sector.

4.2 Conclusion

The impact of climate change on rice yields will depend on actual patterns of climatic factors change in rice growing regions. Both higher maximum and minimum temperature can decrease rice yields due to spikelete sterility and higher respiration losses. At the same time, rice production may be threatened in some especially vulnerable regions, such as those affected by a rise in sea level rise, cyclone, drought, etc which are not considered in the present study. Overall, much uncertainty still exists about the true direction of the impacts of CO_2 and temperature on rice yield.

The DSSAT model has been carried out in this study to see the possible effects of climate change on Boro rice yield in Bangladesh because Boro rice is one of the major food grains which contribute above 58% of total rice production in 2008. 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 25^0C to 30^0C for rice under the climatic conditions of Bangladesh. The simulations results suggest that maximum and minimum temperatures could significant affect on rice yield, and this effect could become more pronounced if temperatures rise in 4^0C. Sensitivity analysis indicates that crop model is sensitive to CO_2 levels and has a positive impact on rice yield. Although higher CO_2 levels in the future would balance the detrimental effects of increased temperatures to some extent but it would not be able to offset them. The model simulations also suggest that changes in rainfall pattern may also adversely affect on rice yield.

If the population grows to 233.2 million by the year 2050, then the problem will be more acute. Currently, maximum area in Bangladesh is under HYV Boro rice cultivation. It is expected that in future the total rice area would be under HYV cultivation. However, even then the rice production is not projected to be adequate to meet the demand. Therefore, development of cultivars that would be able to withstand high temperature (2^0C to 4^0C temperature) and water stress and have greater photosynthesis efficiency may mitigate the production problems projected for the next 50 to 100 years. Besides proper management practices (irrigation and fertilizer applications) would also help to meet the food demand under changing climatic condition in future. Public awareness of the impact of climate change on the agricultural production systems deserves priority consideration, and mitigating technologies must be developed, which will require increased public and private investment.

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